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"A MULTIDISCIPLINARY APPROACH TO SUSTAINABLE DEVELOPMENT GOALS"

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Editorial: ***Uniting Knowledge for a Sustainable and Inclusive Future***

The growing urgency of the UN Sustainable Development Goals (SDGs) underscores the need to unite knowledge across disciplines, institutions, and societies in order to address today's complex environmental, social, and technological challenges. In this global context, University "St. Kliment Ohridski" – Bitola (UKLO) continues to advance sustainability, inclusivity, and open scientific exchange through its Annual International Scientific Conference (AISC).

Organized in the framework of World Science Day for Peace and Development, AISC 2025 provided a multidisciplinary platform that brought together researchers and practitioners from diverse fields to engage in dialogue aligned with the UN 2030 Agenda. The conference reaffirmed that meaningful progress toward sustainable development depends on interdisciplinary collaboration, inclusive participation, and the responsible production and sharing of knowledge.

Selected peer-reviewed papers from AISC 2025 are published in the *UKLO Proceedings*, Vol. 2, No. 1 (2026), as an open-access publication. To further enhance visibility and scholarly impact, the *UKLO Proceedings* is indexed in Google Scholar and Scilit, ensuring that the research is widely discoverable, easily citable, and accessible to the global academic and professional community.

By extending scientific knowledge beyond the temporal and spatial boundaries of the conference, UKLO reinforces its role as a catalyst for sustainable development, evidence-based policymaking, and societal transformation. The outcomes of AISC 2025 extend beyond academic exchange, fostering new research networks, inspiring practical initiatives, and generating ideas with tangible relevance for policy and practice.

We extend our sincere gratitude to the authors, reviewers, and organizers whose dedication and professionalism made this volume possible. We invite readers to explore these pages with curiosity, to discover connections across disciplines, and to engage critically with the ideas presented. **We hope that this collection will inspire dialogue, forge new partnerships, and contribute, however modestly, to building a more sustainable, inclusive, and peaceful future**.

Editor-In-Chief
Prof. Dr. sc. Goran Ilik, Vice-Rector for Science at UKLO

Bitola, 11 May 2026

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CARBON FARMING: A GATEWAY TO PROMOTING SUSTAINABLE AGRICULTURE AND MITIGATING THE IMPACTS OF CLIMATE CHANGE IN THE SOUTHWEST REGION OF CAMEROON

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ABSTRACT

Introduction: *Agriculture, which constitutes approximately 17% of Cameroon's economy, and employs 70% of Cameroon's labor is grappling with substantial challenges posed by climate change. This study explores carbon farming practices, such as cover cropping, agroforestry, and reduced tillage, as climate-smart strategies to promote sustainable agriculture while mitigating the adverse impacts of climate change.*
Methods: *This study employs a mixed-methods approach, involving 27 semi-structured interviews with farmers, exporters, NGOs, and officials from the Ministry of Agriculture, as well as a focus group discussion with community stakeholders. Secondary data review and trade dataset analysis are also incorporated.*
Results: *70% of respondents expressed willingness to adopt at least one carbon farming practice, provided they received adequate training and financial support. Most farmers expressed concern about the potential of reduced yields but were excited by the possibility of trading CO2 captured for extra income. Key barriers identified by Stakeholders include measurement, reporting, and verification (MRV), cost, and regulatory gaps.*
Discussion: *The study concludes that integrating carbon farming into Cameroon's agricultural strategy offers a practical pathway to achieving Sustainable Development Goals 2 and 13. Moreover, it positions Cameroon as a potential regional leader in climate-smart agriculture while balancing economic, environmental, and social priorities.*

Keywords: Carbon farming, climate-smart agriculture, climate change, SDG2, SDG13, adaptation, mitigation

1. Introduction

Cameroon grapples with the impacts of climate change on the lives of Cameroonians and on agriculture, which employs 70% of the population and accounts for about 17.0% of GDP (Musa 2024). A combined effect of these impacts includes food insecurity, inequality, poverty, reduced yields, impacts on health, and forced migration. These effects are visible in many parts of the country, most especially in the Northern regions, which experience dry spells, and the coastal regions, which have become victims of floods and heavy rainfalls (IMF 2024, 32). These challenges are not isolated incidents because, aside from the natural causes, human activities have contributed largely to these unfortunate outcomes, and they include activities such as deforestation, unsustainable agricultural practices, and the burning of fossil fuels.

Despite knowledge of these practices, the state's implementation of measures to address these issues doesn't match prescribed measures on paper. To address these issues, it is important to adopt international best practices that have worked in other countries and can fit within the context of Cameroon. One of such international best practices is carbon farming, a practice that is implemented in some European countries, Brazil, Australia, and the United States (May 2022). In Australia as of 2022, through the crediting and purchasing of emissions reductions by the Government, the Emissions Reduction Fund has delivered 77 million tonnes of greenhouse gas abatement from a total of 217 million tonnes contracted for delivery (Carbon Market Institute "n.d.", 3). This emissions reduction was realized through carbon farming practices.

One of the major sources of greenhouse gases emanates from agriculture; this is because traditional agriculture is known to use fertilizers that contain methane. Carbon farming, on the other hand, is a deviation from conventional farming and involves the use of agriculture in such a way that, rather than emitting greenhouse gases, it sequesters carbon in the soil (Carbon Cycle Institute "n.d."). This helps to enhance soil sequestration capacity, increase agricultural productivity, and at the same time build resilience to drought. How this works is that plants capture and store CO2 from the atmosphere and deposit the carbon into the soils through roots, root exudates, seeds, and plant residues at different depths of the soil profile (Hans 2020, 3). Once the crop decomposes, part of it is later released into the atmosphere, and the rest remains in the soil (organic matter). This practice has several benefits, such as environmental, economic, social, and cultural benefits. The scientific basis of carbon farming is rooted in research conducted by numerous global North research institutes, such as the University of California Davis Institute of the Environment, the 4 per 1000 Initiative, and the Marin Carbon Project.

Taking into consideration the diverse nature of Cameroon's agroecology landscape, there are many ways by which Cameroonian farmers can engage in carbon farming. Building on research conducted by these institutions and acknowledging that carbon farming is an umbrella term for several smart agricultural practices. These carbon farming practices include agroforestry, rotational grazing, companion cropping, crop rotation, cover cropping, perennial crop cultivation, and non-chemical fertilizer and pest control management. This new kind of climate-smart practice will also open doors for farmers to access new revenue streams through carbon credits and enhance long-term soil health and productivity. Cameroon has the potential to adopt this climate-smart practice. It is important we keep in mind, as Green Australia highlights, that, "Every farm is unique, so to maximize the benefits from carbon farming, projects need to be tailored to each farmer's preferences and priorities – and also the landscape they are operating within" (Green Australia, "n.d."). This paper will examine the perspective of farmers and other stakeholders towards the adoption of carbon farming in Cameroon.

1.1.Problem statement

Despite the threats posed by climate change to agriculture in Cameroon, adequate measures designed towards tackling it and promoting sustainable agriculture are underexploited and under implemented. Farmers, lack adequate information, financial incentives, and required expertise to adopt approaches that both enhance productivity and contribute to climate mitigation. Although carbon farming presents a promising pathway for improving soil health, sequestering carbon and unlocking new income streams through carbon credits, it remains largely unexplored. This gap in knowledge and implementation underscores the need to assess stakeholder perspectives, identify barriers to adoption, and evaluate the potential of carbon farming to support sustainable agriculture and climate change mitigation in the Southwest Region of Cameroon.

1.2.Objectives

This study aims to investigate stakeholder perspectives on carbon farming within the Southwest Region of Cameroon and to assess the extent to which farmers are willing and able to adopt carbon-farming practices. It further seeks to identify the perceived benefits, challenges, and enabling conditions associated with adoption, providing an evidence-based understanding of how carbon farming may serve as a pathway to sustainable agriculture and climate-change mitigation in the region

1.3 Significance

This study is timely because it comes at a time when Cameroon is grappling with the impacts of climate change on every sphere of life. This research will assist the government of Cameroon to better shape its agricultural strategy and National Determined Contribution to address SDG 2 and SDG 13. It's also important to Cameroonian farmers because it provides a feasible approach to sustainable agriculture and extra income to farmers through the exchange of carbon credits.

2. Literature Review

Cameroon, like many developing countries in Africa, is seriously affected by the impacts of climate change, and these impacts are not limited to droughts, heatwaves, flooding, and food insecurity. These impacts exacerbate the gap between the rich and the poor, with women being more vulnerable to the impacts. While it is true that the government, civil society organizations, and local communities have adopted several climate-smart practices to curb the impacts of climate change, the effects of climate change remain visible across many geographic and demographic groupings in Cameroon. This prompts a call to action, and sometimes reliance on the best available science and internationally best practices is a promising way to go about climate adaptation and mitigation practices. Carbon farming presents Cameroonian farmers with an opportunity to not only grow their crops sustainably but also mitigate the impacts of climate change and presents an avenue for farmers to generate income. This literature review will examine the work done by different scholars and experts in the field of climate-smart agriculture in Cameroon. It will also analyze the gaps in literature and make a compelling case for why Cameroon should engage in carbon farming.

Tankou C.M.'s analysis of climate-smart agriculture through passive and active strategies acknowledges the role played by smart agriculture in tackling the threats of climate change on our agricultural system (Tankou 2023). According to him, a changing climate will impact temperature and precipitation, which are very essential for crop growth. The resulting impact is an increase in mean annual temperature by more than 2°C by the end of this century–reducing crop productivity across sub-Saharan Africa (Tankou 2023). Against this background, he recommended that the resilience of agricultural systems needs to exploit sustainable preservation strategies. Adopting climate-smart agriculture helps farmers adapt and prepare for impacts to preserve and improve their livelihoods.

He went further in his analysis to shed more light on how these adaptive measures, which encompass active and passive methods in climate-smart agriculture, can be used to tackle climate change. The distinction Tankou makes between active (agroforestry), and passive (site and species selection) adaptation strategies is practical and grounded in real-world farming conditions. Agroforestry, as an active measure, represents a forward-thinking alternative to more destructive practices like slash-and-burn, helping to sequester carbon and preserve biodiversity. Passive strategies such as choosing appropriate sites and resilient crop varieties are equally critical, especially where resources are limited and formal infrastructure is lacking (Tankou 2023).

He concluded by stating that agricultural systems remain largely rain-fed and underdeveloped because most farmers have limited financial resources, limited access to infrastructure, and disparate access to information (Tankou 2023). His study is limited to climate adaptation measures. The research on carbon farming explores agriculture as both an adaptation and a mitigation measure, thereby giving farmers alternatives to farmers in the southwest region. The paper widens the scope of benefits: not only does it protect and restore soils, but it also gives farmers in the Southwest region of Cameroon potential new income streams through carbon credits. This synthesis could guide not just policy, but on-the-ground practices, benefitting both the environment and farmers' livelihoods across Cameroon.

DingaTambi's analysis the role of climate-smart agriculture in sustainable food production among producer organizations in Cameroon (Dinga 2024). Tambi identified several challenges faced by farmers in Cameroon, particularly in the Southwest region, which impact various stages of agricultural activities (Dinga 2024). Among these challenges, financial difficulties and climate change emerge as the most significant. Tambi also highlighted the limited understanding of farmers regarding the impacts of climate change on their agricultural output. To address these challenges, Tambi mentioned state efforts, such as subsidizing agricultural inputs like nitrogen, phosphorus, and potassium fertilizers, and urea. According to him, reinforcing farmers' capacity through efficient, ecological, and environmentally friendly agricultural methods is a good solution towards increased crop yield and the eventual empowerment of farmers. His analysis, which touches on subsidization of agricultural inputs by the state to curb the challenge of financial shortfalls, undermines the contributing impacts of fertilizers to climate change.

Sadly, these assistance programs lack the prerequisite technical knowledge, which poses limitations that goes beyond inefficient use of farm inputs and machines for agriculture, which has effects on climate change. Also, in the wake of European Union regulations like the Caborn Border Adjustment Mechanism, which targets fertilizers on agricultural inputs, Tambi's suggestion is bound to hinder the exportation of agricultural products from Cameroon to the E.U.

This paper focusing on carbon farming is proposing new methods of farming that use agriculture as a tool for climate mitigation. The practices we are suggesting will make farmers' crops more resilient to climate change and make them compliant with the regulations of one of her largest trading partners, the European Union. It also offers solutions to the challenge of finance by making it possible for Cameroonian farmers through agricultural practices that sequester carbon to generate credits and trade them in the Carbon market.

Friederike Schilling et al., analyzed the opportunities and challenges of carbon farming for smallholder farmers, highlighting the momentum gained by natural climate solutions towards attaining net-zero emissions (Friederike 2023). According to them, agricultural practices that increase carbon sequestration in soils and plants and reduce or avoid greenhouse gas (GHG) emissions in agricultural production possess the potential to meet net-zero (Friederike

2023,1). Carbon farming, which involves agroforestry, cover crops, improved crop rotations, reduced tillage, retaining of crop residues, the addition of biochar, and manure management, improves the rate at which CO2 is removed from the atmosphere and transformed into plant material (Friederike 2023,2).

This approach to agriculture has the potential to meet contemporary global challenges of realizing net-zero by 2050 and resilient food systems to address persistently high levels of food insecurity (Friederike 2023, 12). Drawing from different literatures, they established a distinction between carbon farming and carbon farming practices (Friederike 2023, 3). By carbon farming practices, they refer to agricultural management practices that either avoid, reduce the release of greenhouse gas emissions, or promote active sequestration of carbon in vegetation and soils. They are not limited to agroforestry, crop and soil management, and livestock management. Meanwhile, carbon farming is a business model that remunerates farmers for the implementation of carbon farming practices. As part of their framework, though limited to small-scale farmers, they added intermediaries (Friederike 2023, 5).

These intermediaries have numerous roles, including engaging with the smallholder farmers at different stages of the process, providing information or inputs, and serving as a means for aggregating farmers into carbon farming projects and engaging in monitoring, reporting, and verification (MRV). Looking at some of the challenges they identified, the absence of a well-developed agricultural carbon market was listed as one of the barriers to the development of agricultural carbon markets. According to them, this is because the recognition of carbon farming practices in international climate change discussions and negotiations only got international attention at the UNFCCC's COP27 in 2022. One of the challenges they identified associated with carbon farming is the risk of low or no additionality. They also highlighted some benefits of carbon farming to farmers, which include additional sources of profits and being in alignment with global sustainability standards.

This paper expatiates on this issue further and contextualizes its application in the Southwest region of Cameroon. This policy paper makes use of data collected on the field to provide solutions to the challenges highlighted above, such as the need for a legal framework for carbon markets, resources for monitoring, reporting, and verification, and financial resources.

Verina Ingram et al. analyzed the implications of cocoa as the main driving force causing deforestation in Cameroon (Verin 2025). In their analysis, they hinted that cocoa, a crop foreign to Africa's soils, was introduced in the colonial times as a pioneer export commodity cash crop on fertile, converted forested lands (Verin 2025, 1). According to them, Africa, which accounts for over 76% of global cocoa production, takes the lead in the production of cocoa, with Cameroon amongst the leading exporters of the crop. This lead comes at the cost of Cameroon's forest, accounting for over a quarter of forest lost in Cameroon between 2001 and 2020. Citing existing policies on the ground, such as the National Agricultural Investment Plan 2020–2030, cocoa is seen as the future of Cameroon, and the state has allocated 40,000 million CFA towards its development (Verin 2025, 5). To regulate the impact cocoa production has on forest cover in Cameroon, the European Union adopted several policies, like the Deforestation Regulation. The aim of this policy is to reduce the deforestation caused by cocoa (deforestation-free) by requiring that the cocoa be sourced from farmland that has not been deforested since December 31, 2020 (Verin 2025, 2).

At the national level, the Ministry of Forestry and Wildlife, which regulates forests in Cameroon, has highlighted that several farmers fail to obtain permission from the state before cutting down trees. Also, they stated that only a few stakeholders (NGOs, government, academia, development organizations) they interviewed indicated they have been engaged in discussions on how to actively protect remaining forests. Using a sample size representing

five cocoa-producing villages with two located in forested areas and two in degraded forest areas, they identified. Participants from this interview who stated that financial pressures and climate shocks are some of the reasons for deforestation. (Verin 2025, 11).
Their work focuses solely on cocoa as a driver of deforestation in Cameroon. However, our paper focuses on carbon farming as a solution for sustainable agricultural practices in Cameroon. This has some implications for cocoa farmers because they will be able to cultivate cocoa while conserving the forest and not be victims of regulations that target cocoa in the EU that are not deforestation-free. It will also make it possible for farmers to cultivate their crops free of the pressures associated with climate change, such as black pods.

Based on Cameroon's national development strategy 2020-2030, the government plans to increase agricultural productivity (National Development Strategy 2020-2030, 7). This national strategy is timely and comes at a time when the government of Cameroon is seeking to become a developed economy. This will entail investments in major sectors that constitute the country's economy, such as agriculture. The challenge with the document is the realization of this big vision, especially with the impacts of climate change on agricultural output. This paper, which focuses on carbon farming, provides a timely solution for the realization of this grand vision. With a careful step-by-step implementation, Cameroon will not only realize her climate and agricultural goals but will place the country as a major hub for sustainable agriculture.

Despite the above research, no study has examined farmer perceptions of carbon farming in Cameroon using a mixed-methods empirical approach, nor has any study explored its market, regulatory, and adoption barriers in the Southwest Region.

3. Methodology

The study employed a purposive sampling strategy to intentionally recruit respondents with direct experience in farming or climate-smart practices, as this approach is well suited for research requiring information-rich cases and domain-specific expertise (Palinkas et al., 2015). The initial sample size target of 30 individual interviews and two focus group discussions was guided by methodological recommendations suggesting that thematic saturation in qualitative and mixed-methods agricultural studies is commonly reached between 20 and 30 participants (Guest et al., 2006). Sampling was conducted through agricultural cooperatives, local networks, and extension contacts in Southwest Cameroon. However, due to recurrent lockdowns, mobility restrictions, and regional insecurity, the final realized sample was adjusted to 27 individual interviews and one focus group discussion. Data collection was conducted using a Kobo Toolbox digital questionnaire administered through mobile devices, which ensured safety, accessibility, and data accuracy under field constraints.

Investment willingness was analyzed in R using self-reported categorical ranges, which were converted into numeric midpoints (e.g., "Up to 10,000 XAF" = 5,000 XAF; "10,001–50,000 XAF" = 30,000 XAF; "More than 50,000 XAF" = 75,000 XAF) to enable continuous quantitative analysis. Climate-smart and carbon-farming practice variables were identified using regex-based matching and standardized into binary indicators (1 = adopted, 0 = not adopted). An adoption intensity score was generated by summing these indicators, after which respondents were categorized into four ordered groups (0, 1, 2, or 3+ practices). Willingness-to-invest values were cleaned, stripped of non-numeric characters, and converted into CFA francs (XAF).

Descriptive statistics—including means, standard deviations, and mean ±1 SD ranges—were used to summarize central tendency and variability across adoption groups. Normality and homogeneity assumptions were evaluated to determine appropriate inferential

tests; one-way ANOVA was applied when assumptions were met, whereas the Kruskal–Walli's test was used for non-normal distributions. Associations between categorical variables (e.g., adoption level, cooperative willingness) were assessed using Chi-square tests, with Fisher's exact correction applied when expected cell counts were low ($p < .05$). Willingness to adopt carbon farming was examined using proportional descriptive statistics. Climate-smart practices were extracted by pivoting all "current practice" fields into long format, cleaning binary selections ("1," "yes," "true"), and aggregating frequencies to identify the three most adopted practices. All visualizations were produced in ggplot2 using standardized color palettes to enhance clarity, reproducibility, and interpretability.

3.1.**Results**

Figure 1: The boxplot shows that farmers' annual willingness to invest in carbon-farming practices varies across adoption levels but remains broadly comparable. Farmers with zero practices reported tightly clustered willingness values around 70,000–75,000 CAF, whereas those practicing one or two methods showed greater dispersion, ranging from approximately 10,000 CAF to above 70,000 CAF, with median values near 50,000–55,000 CAF. Farmers already adopting three or more practices again displayed concentrated willingness around the 70,000–80,000 CAF range. Although medians differ slightly across groups, the substantial overlap between interquartile ranges indicates no statistically distinct separation in investment willingness by practice level.

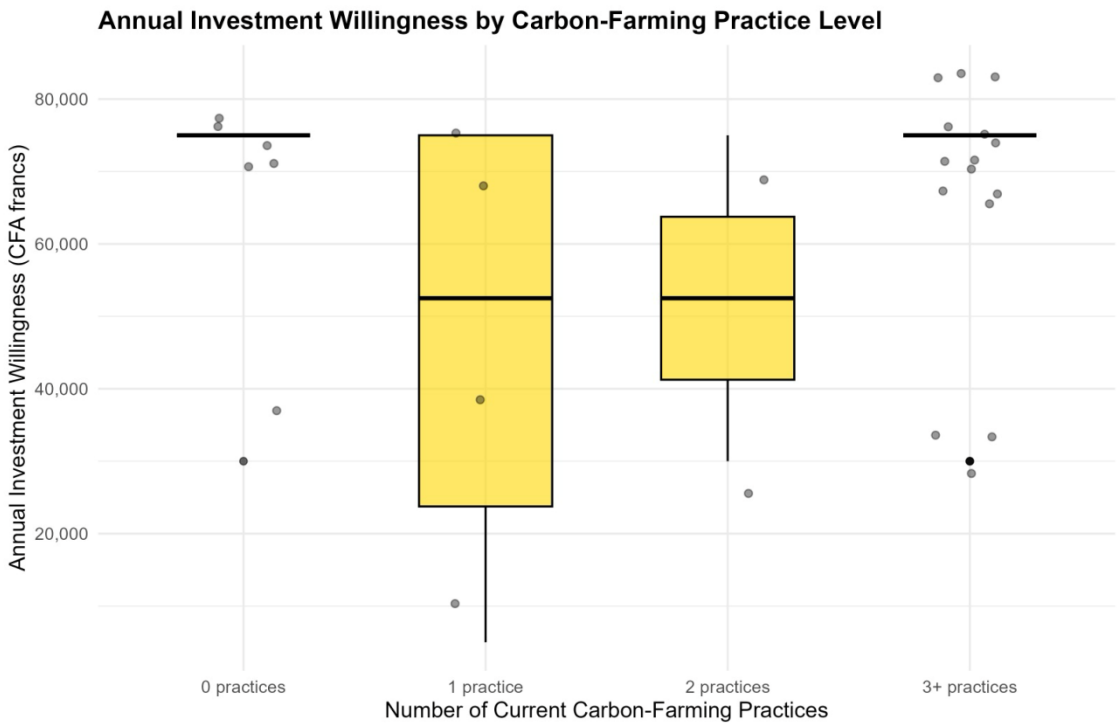

Figure 1: Annual investment willingness by number of Carbon-Farming Practices

The results indicate that farmers' financial willingness to invest in carbon-farming does not vary significantly with the number of climate-smart practices they currently adopt. Although median investment levels are slightly higher among farmers implementing one or two practices, the substantial overlap in distributions suggests that investment intentions remain highly heterogeneous and are influenced more by external constraints than by current engagement in carbon-farming. This pattern likely reflects broader structural barriers—including perceived financial risk, limited disposable income, and uncertainty about the

reliability or fairness of carbon-credit benefits, which can temper farmers' readiness to make out-of-pocket investments even when they are conceptually supportive of climate-smart agriculture. Collectively, these findings underscore the need for targeted financial instruments, transparent carbon-market communication, and strengthened institutional support to translate general willingness into sustained and scalable investment in carbon-farming practices.

Figure 2 below presents the results of the thematic analysis conducted on the focus group transcript, showing the frequency with which farmers raised specific issues related to carbon farming and climate-smart agriculture. The most frequently mentioned theme was high agrochemical costs, cited 41 times. Farmers repeatedly emphasized that rising input prices—particularly chemicals for pest and disease control—are a major constraint to cocoa productivity and a barrier to adopting improved farming practices. This is closely followed by interest in carbon farming (38 mentions), indicating that although farmers face structural limitations, they are willing to adopt carbon-farming practices when these practices are clearly explained and accompanied by tangible benefits such as income generation, improved soil fertility, or reduced reliance on chemical inputs. Mentions relating to climate impacts on cocoa (20 occurrences) also featured prominently, highlighting farmers' lived experiences with changing rainfall patterns, increased pest outbreaks (especially black pod), and declining yields—factors that directly shape their perceptions of carbon farming as a potential adaptation and resilience-building strategy.

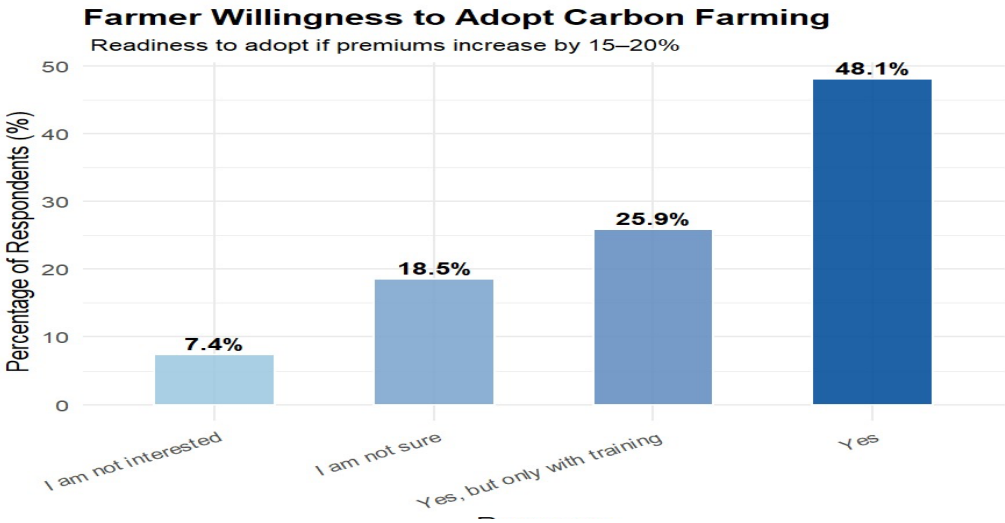

Figure 2: Farmers Willingness to adopt Carbon Farming

The results show a generally favorable disposition toward adopting carbon farming among surveyed farmers in the South-West Region of Cameroon. Nearly half of the respondents (48.1%) indicated a clear willingness to adopt carbon farming practices if premiums increased by 15–20%, demonstrating a strong sensitivity to economic incentives. An additional 25.9% expressed willingness to adopt only if adequate training is provided, underscoring the centrality of knowledge and capacity-building as enabling conditions for adoption. Together, these two groups represent more than 74% of respondents, suggesting that both financial motivation and technical support play decisive roles in influencing behavioral change and uptake of low-carbon agricultural practices.

In contrast, a smaller proportion of farmers exhibited reluctance or uncertainty toward adoption. About 18.5% responded that they were unsure, reflecting ambiguity regarding the

benefits, requirements, or long-term viability of carbon farming within local production systems. A minority (7.4%) indicated no interest at all, suggesting structural, informational, or contextual barriers that outweigh potential incentives. Overall, this distribution indicates that while the majority of farmers are receptive to transitioning into carbon farming—particularly when supported by economic and capacity-building mechanisms—a targeted combination of financial incentives, farmer training, and risk-reducing interventions remains essential to ensure broad and sustainable adoption across the region

4. Discussion

The findings of this study provide a compelling understanding of stakeholder perspectives on carbon farming in the Southwest Region of Cameroon and reveal both strong potential and notable constraints for adoption. Quantitative results show that farmers' willingness to adopt carbon-farming practices is generally high, with more than 74% of respondents expressing readiness to adopt if provided with either financial premiums or technical training. This indicates that economic incentives and capacity-building remain the most decisive drivers of behavioural change. The analysis of annual investment willingness further demonstrates that farmers across all levels of current climate-smart practice adoption are willing to invest modest but comparable amounts (typically 30,000–75,000 XAF). This suggest that investment readiness is shaped less by current exposure to carbon-farming practices and more by broader financial limitations, perceived risks, and uncertainty regarding carbon-credit benefits. These insights align with existing literature showing that financial constraints and perceived market instability often limit farmers' engagement in climate-smart agriculture, even when environmental attitudes are positive(Dinga 2024).

Qualitative findings deepen this understanding by revealing the specific structural challenges shaping farmers' decisions. The most prominent themes revolve around the high costs associated with agrochemicals, climate-induced yield losses, and the growing interest in carbon farming. These themes underscore the intricate interplay between day-to-day production pressures and long-term sustainability concerns. The recurring emphasis on interest in carbon farming suggests that farmers view it not just as a mitigation tool but as a strategy to stabilize yields and reduce reliance on increasingly expensive inputs. However, concerns over monitoring, reporting, and verification (MRV), regulatory uncertainty, and fears of reduced productivity mirror barriers documented in other African contexts and stress the need for credible institutional frameworks (Bronagh 2024). Importantly, farmers' enthusiasm about earning income through carbon credits underscores carbon farming's potential contribution to SDG 2 (Zero Hunger) and SDG 13 (Climate Action), demonstrating that well-designed programs could simultaneously improve livelihoods and enhance resilience to climate change.

Collectively, these results point to a clear opportunity: carbon farming is both conceptually accepted and practically relevant for farmers in the Southwest Region. However, its successful scaling depends on strengthening financial incentives, improving access to training, and building trustworthy regulatory systems. Tailoring interventions to local agroecological realities, while ensuring transparency, fair benefit-sharing, and long-term support, is crucial for translating emerging willingness into measurable climate and agricultural outcomes. This study presents evidence that carbon farming could play a significant role in Cameroon's pursuit of sustainable agriculture. However, this potential is contingent on addressing implementation challenges through coherent policy action, institutional collaboration, and sustained stakeholder engagement.

5. Conclusion

This study identifies carbon farming as a viable pathway for strengthening sustainable agriculture and climate resilience in the Southwest Region of Cameroon. Farmers demonstrated strong conceptual willingness to adopt carbon-farming practices.However, investment readiness remained modest and did not increase consistently with the number of practices currently used, indicating that financial decisions are influenced more by income constraints, perceived risks, and uncertainty about carbon-credit benefits than by practice engagement alone. These findings highlight the need for clearer incentives, stronger institutional frameworks, and targeted capacity-building to convert willingness into sustained adoption. By addressing issues such as market volatility, additionally, permanence, and benefit-sharing transparency, Cameroon can better align carbon-farming initiatives with its agricultural priorities and NDC commitments while advancing progress toward SDG-aligned climate and livelihood goals.

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ESG PERFORMANCE IN THE INSURANCE INDUSTRY: A STUDY OF THE REPUBLIC OF NORTH MACEDONIA

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ABSTRACT

Introduction: *The integration of environmental, social, and governance (ESG) factors within the insurance industry is increasingly recognized as a key determinant of financial stability, competitiveness, and sustainable growth. This research investigates how ESG performance influences risk management, investment strategies, and product development within insurance companies, with a specific focus on the insurance market in the Republic of North Macedonia. The study also explores the evolving regulatory landscape and the growing expectations of stakeholders regarding transparency and accountability in ESG reporting.*
Methods: *The integration of environmental, social, and governance (ESG) factors within the insurance industry is increasingly recognized as a key determinant of financial stability, competitiveness, and sustainable growth. This research investigates how ESG performance influences risk management, investment strategies, and product development within insurance companies, with a specific focus on the insurance market in the Republic of North Macedonia. The study also explores the evolving regulatory landscape and the growing expectations of stakeholders regarding transparency and accountability in ESG reporting.*
Results: *Findings indicate that ESG integration in North Macedonia's insurance sector remains at an early stage, with varying levels of maturity across companies. Environmental and social aspects are less developed compared to governance practices. However, a growing recognition of ESG's financial relevance and its role in regulatory compliance and risk mitigation is evident. The results also suggest that companies adopting proactive ESG strategies demonstrate improved resilience, reputation, and long-term performance.*
Discussion: *The study concludes that ESG principles represent not only an ethical and regulatory requirement but a strategic imperative for the long-term sustainability of the insurance industry. Strengthening institutional capacity, regulatory frameworks, and stakeholder awareness is essential to accelerate the transition toward sustainable insurance. Future research should focus on refining ESG measurement models and examining the relationship between ESG factors and financial outcomes in emerging markets.*

Keywords: ESG principles, sustainability, insurance industry, risk management

INTRODUCTION

In the context of intensified global trends toward sustainable management and social responsibility, this research aims to examine the readiness, engagement, and strategic orientation of insurance companies in the Republic of North Macedonia with regard to the

integration of Environmental, Social, and Governance (ESG) principles into their business operations. Through a quantitative analysis based on structured questionnaires, this doctoral dissertation will analyze the level of awareness of ESG principles, the manner in which these principles are integrated into risk assessment processes, product development, investment strategies, and corporate governance, as well as the impact of ESG on the competitiveness, rating, and regulatory compliance of insurance companies. The research will also identify the main challenges and opportunities perceived by the sector in relation to ESG, with the purpose of proposing directions for improving sustainability and the regulatory framework.

Over the past decade, the criteria of environmental protection, social responsibility, and corporate governance have evolved into strategic pillars of modern corporate decision-making and investment planning. As emphasized by KPMG (2011)[1], sustainability is no longer a matter of voluntarism, but an imperative of modern business operations—especially for industries that rely on long-term risk assessment and stability. In this sense, the insurance sector—due to its inherent connection with the management of complex and long-term risks—is particularly sensitive to ESG factors. Integrating these criteria into the business strategy of insurance companies not only strengthens their resilience and reputation but also represents a prerequisite for sustainable growth and regulatory compliance in an increasingly dynamic and uncertain global environment.

The limited availability of empirical research analyzing the relationship between ESG factors and the insurance industry indicates the existence of a significant research gap that remains insufficiently explored. This is also true for the insurance market in the Republic of North Macedonia, where the application of environmental, social, and governance criteria in strategic decision-making processes and within the regulatory framework is still in its initial stage of development.

Therefore, the choice of this topic is motivated by the need to examine whether, and in what way, environmental, social, and governance performance affects the operations of insurance companies—particularly regarding their profitability, risk exposure, and long-term sustainability—taking into account the specific institutional, regulatory, and market context of the Republic of North Macedonia. In this sense, the research has the potential not only to contribute to the enrichment of academic literature but also to provide practical guidelines for fostering the development of sustainable insurance at the national level.

ESG, on the other hand, represents an analytical framework used to assess non-financial risks and opportunities in corporate operations. It serves as a practical instrument, particularly relevant for investors, insurance companies, and other financial institutions, for evaluating companies' performance in relation to:

- **Environmental aspects** (pollution control, greenhouse gas emissions, waste management, energy and natural resource efficiency, adaptation to climate change);
- **Social aspects** (employee relations, occupational health and safety, consumer rights, community engagement, respect for human rights);
- **Governance aspects** (operational transparency, anti-corruption efforts, structure and independence of governing bodies, regulatory compliance, business ethics, and accountability toward stakeholders).

In other words, ESG can be understood as the operationalization of sustainability—a set of indicators and policies through which companies implement and demonstrate their

[1]KPMG. 2011. *Sustainability Reporting: A Guide to Responsible Business*. Amsterdam: KPMG.

sustainable orientation. ESG is particularly important in the corporate and financial spheres, as it enables comparability and accountability.

PROBLEM STATEMENT

The subject of this research is the analysis of the influence of environmental, social, and governance (ESG) performance on the insurance industry, with particular emphasis on the insurance market of the Republic of North Macedonia. The study aims to identify the ways in which ESG factors affect the business behavior of insurance companies, as well as the decision-making processes of policyholders when selecting insurance products and services.

This research is directed toward a thorough examination of the relationship between environmental performance, social responsibility, and corporate governance, and the exposure of insurance companies to significant institutional and market risks. The focus is placed on two core segments of the insurance industry—life and non-life insurance—which, although operating within different business frameworks, share a common sensitivity to long-term risks and external shocks.

The study analyzes the hypothesis that the integration of ESG principles leads to the enhancement of long-term sustainability, reputation, and market competitiveness within the insurance sector. Additionally, it tests the hypothesis that ESG factors represent a relevant and increasingly significant criterion in the decision-making process of policyholders when choosing an insurance product, indicating a shift in perception and a growing awareness of sustainability within society.

In light of current trends emphasizing the growing influence of ESG factors in financial decision-making and risk management processes, the research also seeks to determine whether the integration of sustainable practices and policies into corporate governance can act as a stabilizing mechanism. More specifically, it investigates whether improved ESG strategies can reduce the likelihood of financial distress while simultaneously strengthening institutional capacity to adapt to economic shocks.

In doing so, this doctoral dissertation contributes to deepening the understanding of the preventive and adaptive value of ESG frameworks within the specific context of the insurance industry, as a key driver of systemic stability and market trust.

The research focuses on two key directions:

1. **ESG as a strategic orientation of insurance companies** – this dimension examines whether and how insurance companies integrate the ESG agenda into their business strategies, policies, and governance practices. Particular attention is given to the degree of transparency in the disclosure of ESG data, the implementation of sustainable practices, and the establishment of corporate governance mechanisms that support long-term development and risk resilience.

2. **ESG as a decision-making factor in policyholder behavior when purchasing insurance products** – this dimension analyzes the perceptions, attitudes, and preferences of clients regarding ESG criteria. It explores whether consumers take into account the ESG performance of insurance companies when making purchasing decisions, as well as whether ESG reputation influences their trust, loyalty, and willingness to engage in long-term cooperation.

HYPOTHESES

Hypothesis1:

"The integration of ESG principles leads to the enhancement of long-term sustainability, reputation, and market competitiveness within the insurance sector."
This hypothesis assumes that insurance companies, despite the specific characteristics of the national market, recognize the value of integrating environmental, social, and governance factors into their processes of strategic planning, risk management, product offering, and stakeholder relations.

Hypothesis2:

"ESG factors represent a relevant and increasingly significant criterion in the decision-making process of policyholders when choosing an insurance product, indicating a shift in perception and greater awareness of sustainability within society."
This hypothesis is based on the assumption that, when selecting insurance products, policyholders increasingly consider the non-financial performance of companies—such as environmental responsibility, social engagement, and transparency in corporate governance.

OBJECTIVES OF THE RESEARCH

In order to confirm or reject the proposed hypotheses, the research pursues several specific objectives:

- To determine whether ESG principles are incorporated into the strategic planning of insurance companies in the Republic of North Macedonia.
- To analyze whether, and to what extent, ESG orientation influences the behavior of policyholders when selecting insurance products.
- To confirm that ESG practices at the global level have a positive impact on the competitiveness and stability of insurance companies.
- To propose concrete recommendations for improving ESG implementation within the insurance sector of the Republic of North Macedonia.

The main objective of this research is to gain a deeper understanding of how the integration of environmental, social, and governance criteria within strategic risk management and business decision-making affects the overall operations, stability, and long-term resilience of insurance companies. Furthermore, the research aims to identify the potential of ESG practices to serve not only as instruments for enhancing reputation or ensuring regulatory compliance, but also as a fundamental mechanism for reducing institutional and financial risks within the insurance market.

RESEARCH TASKS

To achieve the above-mentioned objectives, the research includes the following tasks:

- Conduct a review of relevant academic and professional literature on ESG and the insurance sector.
- Analyze successful ESG practices among leading insurance companies at the global level.
- Conduct a survey among representatives of insurance companies and policyholders in the Republic of North Macedonia, in order to test Hypotheses 1 and 2.
- Process and analyze the collected data and develop conclusions and recommendations based on the research findings.

SIGNIFICANCE

This study is of both academic and practical importance. Academically, it contributes to filling a significant gap in the literature on the intersection between ESG performance and the insurance industry, particularly in emerging markets. By analyzing the Macedonian insurance market, the research provides empirical evidence that can enhance the global understanding of how ESG integration influences financial stability, competitiveness, and long-term sustainability within insurance systems.

From a practical perspective, the research offers valuable insights for insurers, regulators, and investors. It demonstrates that embedding ESG principles into risk management and investment decisions can strengthen resilience against environmental and social shocks while improving transparency and accountability. Moreover, it provides guidance for policymakers on developing regulatory frameworks that promote responsible and sustainable insurance practices.

Ultimately, this aricle underscores that ESG integration is not merely a compliance requirement but a strategic necessity. By adopting proactive ESG engagement, insurance companies in North Macedonia can enhance their competitiveness, contribute to sustainable economic growth, and position themselves as leaders in responsible financial intermediation in the region.

LITERATURE REVIEW

This research represents a significant contribution to the contemporary scientific discussion on ESG, particularly due to its focus on the insurance industry—a sector that has traditionally been underexplored within the domain of sustainable finance, despite its crucial role in absorbing systemic risks and supporting long-term economic stability. Unlike other financial institutions, insurance companies operate within a specific and often complex regulatory environment, where their obligations are characterized by structural time mismatches and substantial exposure to long-term, systemic, and catastrophic risks.

There are numerous academic studies analyzing the effects of ESG factors on corporate finance. Researchers in these studies seek to measure the benefits of integrating ESG values into corporate management. For instance, an analysis conducted by Friede,[2] Busch, and Bassen (2015)—encompassing more than 2,200 empirical studies—shows that approximately 90% of the analyzed research identifies a positive relationship between ESG performance and corporate financial outcomes. Furthermore, a study by the NYU Stern Center for Sustainable Business, which examined over 1,000 studies published between 2015 and 2020[3], concludes that improved ESG practices are associated with enhanced financial stability, greater operational efficiency, and lower costs of capital. These findings indicate that the integration of ESG factors contributes not only to sustainability but also to the improvement of companies' overall financial performance.

One of the central themes in contemporary sustainable finance literature concerns the question of whether a high ESG profile of companies positively affects their financial performance and entrepreneurial capacity. Within the theoretical framework, numerous studies suggest that investors who are more risk-averse tend to prefer investing in companies

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[2] Friede, Gunnar, Timo Busch, and Alexander Bassen. 2015. "ESG and Financial Performance: Aggregated Evidence from More than 2,000 Empirical Studies." *Journal of Sustainable Finance & Investment* 5 (4): 210–33. https://doi.org/10.1080/20430795.2015.1118917

[3] NYU Stern Center for Sustainable Business and Rockefeller Asset Management. 2021. *ESG and Financial Performance: Uncovering the Relationship by Aggregating Evidence from 1,000 Plus Studies Published between 2015–2020.* New York: NYU Stern School of Business.

with higher ESG standards, due to the perception of these companies as more stable and resilient to systemic and non-financial risks (Heinkel, Kraus, & Zechner, 2001).[4]
Furthermore, there is a lack of standardized indicators and consistent approaches for measuring ESG performance in the insurance industry, which limits comparability and the quantitative assessment of the impact on financial and non-financial outcomes (OECD, 2021)[5]. Therefore, research in this area remains in its early stages, and further studies are required to account for the specific characteristics of the insurance sector within the ESG context.

This gap is precisely what motivated me to conduct an analysis focused on the insurance sector—a sector that plays a pivotal role in the functioning of the overall economic system. Thus, examining the financial stability of insurance companies and its relationship with ESG policies has proven to be of exceptional importance.

Regarding the confirmation of the benefits of implementing ESG principles in the operations of insurance companies, the academic literature presents divided opinions. Some studies confirm that high ESG performance can lead to increased financial stability, enhanced resilience to systemic and unexpected risks, and lower costs of capital (Liu et al., 2021; Trinks & Scholtens, 2017).[6] In this context, ESG can be regarded as a risk-mitigation mechanism with a direct influence on the long-term sustainability and competitiveness of insurance companies.In the context of the insurance industry, however, academic research remains limited in the use of ESG scores as an instrument for empirical analysis.
Consequently, there is a genuine need for deeper research examining the intersection between ESG performance and financial stability in the insurance sector—especially in the context of global challenges such as climate change and the transition toward a green economy.

This gap in the literature represents a significant research potential, particularly in the context of developing markets such as the insurance market of the Republic of North Macedonia, where ESG factors are still not widely integrated into corporate decision-making and investor communication.

As part of this research, a systematic review of relevant academic literature, as well as professional and applied sources, was conducted in order to comprehensively determine the existing knowledge on the relationship between ESG factors and financial performance. The search encompassed several major academic databases, including: Academy of Management Journals, ABI/Inform, EBSCO, Emerald Insight, Google Scholar, Oxford Journals, SAGE Publications, ScienceDirect, SpringerLink, and Web of Science.
In addition, an extended search was carried out in databases containing unpublished academic works and working papers, such as EconBiz, NBER (National Bureau of Economic Research), RePEc (Research Papers in Economics), and SSRN (Social Science Research Network).

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[4]Heinkel, Robert, Alan Kraus, and Josef Zechner. 2001. "The Effect of Green Investment on Corporate Behavior." *Journal of Financial and Quantitative Analysis* 36 (4): 431–449. https://doi.org/10.2307/2676221.
[5]OECD. 2021. *Mobilising Institutional Investors for Financing Sustainable Development in Developing Countries*.https://www.oecd.org/daf/financing-sustainable-development/development-finance-standards/mobilisation.htm
[6]Liu, Bilu, Xun He, Peilin Gao, and Xin Chang. 2021. "Does ESG Performance Impact Financial Performance? Evidence from the Global Insurance Industry." *Finance Research Letters* 41: 101870. https://doi.org/10.1016/j.frl.2020.101870.
Trinks, Pieter J., and Bert Scholtens. 2017. "The Opportunity Cost of Negative Screening in Socially Responsible Investing." *Journal of Business Ethics* 140 (2): 193–208. https://doi.org/10.1007/s10551-015-2684-3.

RESEARCH METHODS AND TECHNIQUES

This research employs a combination of quantitative and qualitative methods in order to provide a comprehensive approach to analyzing the impact of ESG performance on the insurance industry, particularly within the context of the insurance market in the Republic of North Macedonia.

Survey Method

The research utilizes the survey method through the application of two parallel questionnaires distributed to different target groups:

Questionnaire for insurance companies, designed to determine the level of ESG integration within their strategies, processes, products, and stakeholder communication. The survey includes questions related to applicable regulations, ESG policies, reports, and sustainability-related activities. This method is primarily aimed at testing Hypothesis 1.

Questionnaire for individuals (policyholders), aimed at examining whether and to what extent ESG factors influence their decision-making when selecting an insurance product, which is directly related to Hypothesis 2.

Comparative Analysis Method

In the third phase, a comparative analysis is conducted between the results obtained from the Macedonian market and best ESG practices at the global level. The purpose of this analysis is to provide insights into the positioning of the domestic insurance sector in relation to international trends, as well as to offer specific guidelines and recommendations.

Statistical Processing and Data Analysis

The quantitative data collected from the surveys will be processed using descriptive analysis, with the aim of confirming or rejecting the proposed hypotheses. Appropriate software, *Microsoft Office Excel*, will be employed to support data processing and evaluation.

RESEARCH FINDINGS AND RESULTS

Based on the results obtained from the distributed questionnaire addressed to insurance companies operating in the Republic of North Macedonia, the following key finding emerged:

Finding: The integration of ESG factors and risks within the insurance sector of the Republic of North Macedonia has not yet gained significant momentum. Over the past decade, the Macedonian insurance sector has demonstrated a notable increase in awareness regarding sustainability, ESG issues, and associated risks; however, it is evident that ESG factors have not yet achieved substantial advancement in practice.

The companies participating in the research are positioned at varying levels of development concerning the integration of ESG principles into their business operations. This differentiated progress stems from several factors, including institutional maturity, resource availability, corporate culture, and the degree of regulatory compliance. According to the obtained results, the companies can be classified into three main categories of ESG maturity: Initial, Advanced, and Established.

Table 1: Classification of Companies by ESG Integration
Source: Author's own research,2025.

Criterion	**Initial Companies**	**Advanced Companies**	**Established Companies**
ESG Strategy	No formalized strategy	ESG integrated into certain business segments	ESG fully integrated into corporate strategy
ESG Governance	No dedicated structure	Designated responsible persons/teams	ESG department at the corporate level
Reporting and Transparency	No or minimal disclosure	Partial disclosure based on initial standards	Regular reporting aligned with GRI, TCFD, SASB, etc.
Investment Policies	ESG not included	Basic criteria incorporated	ESG criteria fully integrated as standard
Product Offering	No ESG-related products	Several "green" or "social" products offered	ESG principles embedded across all product lines
Stakeholder Engagement	Limited or formal engagement	Consultations with selected stakeholders	Active and systematic dialogue with all stakeholders
Monitoring ESG Performance	No mechanisms in place	Basic KPIs introduced	KPIs and indicators subject to annual review and improvement
Employee Training and Culture	ESG not part of training	Occasional educational sessions	ESG embedded within organizational culture

Table 2: Environmental Risks Relevant to the Insurance Sector in the Republic of North Macedonia
Source: Author's own research,2025.

Environmental Risk	**Impact on Insurance**
Climate Change (rising temperatures, extreme weather events)	Increased demand for insurance coverage against floods, droughts, and other natural catastrophes; higher levels of damages and claim payouts.
Floods and Erosion	Physical risk to property and infrastructure; necessity for geographically precise risk assessments when underwriting policies.
Air, Water, and Soil Pollution	Increased health risks for the population; impact on health and life insurance portfolios.
Water Scarcity and Droughts	Risk to agricultural insurance and rural area products; affects the stability of premium levels.
Biodiversity Loss and Ecosystem Degradation	Indirect consequences for agricultural and tourism insurance; elevated risks to insured assets.
Increased Regulatory Pressure for Environmentally Responsible Practices	Companies are required to adapt their ESG policies; higher administrative and compliance costs.
Energy Transition and Decarbonization	Risks and opportunities associated with investments in green technologies; impact on insurance coverage for industries undergoing transition.

Table 3: Social Risks Relevant to the Insurance Sector in the Republic of North Macedonia
Source: Author's own research,2025.

Social Risk	**Impact on Insurance**
Population Ageing	Increased demand for life and health insurance; higher claim payouts; need for improved actuarial assessment.
Emigration and Decline of the Young Population	Reduced base of potential clients; unstable growth; need for digitalization and product adaptation.

Social Risk	Impact on Insurance
Low Financial and Insurance Literacy	Lack of trust in insurance; weak interest in voluntary products; limited development of ESG-related offerings.
Gender Inequality	Women have limited access to insurance; need for gender-sensitive insurance products.
Marginalization of Certain Groups	Lack of access to insurance services for vulnerable groups; opportunity for developing microinsurance solutions.
Social Tensions and Institutional Distrust	Low trust in the insurance sector; need for increased transparency and accountability.
Unemployment and Economic Insecurity	Citizens tend to avoid purchasing insurance; need for flexible and affordable products.

The following table presents an analytical assessment of the awareness, readiness, and capacities of the insurance sector in the Republic of North Macedonia for the implementation of ESG principles. The evaluations are provided on a scale from 1 (very low) to 5 (very high), with each category accompanied by a brief explanation based on available market data and comparative analyses with other European countries.

Table 4. Assessment of ESG Awareness, Readiness, and Capacities of the Insurance Sector
Source: Author's own research,2025.

Category	Score (1–5)	Explanation
ESG Awareness	2	There is a basic understanding among certain stakeholders, but it remains superficial and limited to the largest insurers. ESG is rarely integrated into core business practices.
Readiness for Implementation	1	Knowledge, resources, tools, and internal training on ESG are lacking. Few insurers have established internal ESG policies or targets.
Regulatory Support	2	The Insurance Supervision Agency demonstrates initial interest, but binding guidelines or developed instruments for ESG supervision are still absent.
Integration into Strategy	1.5	ESG factors are scarcely included in long-term strategies. The primary focus remains on compliance and operational efficiency.

The comparative analysis presented below aims to examine the ESG practices and the degree of their integration within the insurance sector of the Republic of North Macedonia, compared to those in developed global markets (the EU, the United States, and others). This analysis enables the identification of existing gaps, good practices, and potential areas for improvement.

Table 5: Comparative Analysis of ESG Indicators
Source: Author's own research,2025.

Criterion	Republic of North Macedonia	Global Practices (EU/US and others)
ESG Strategy	Partially present in some companies	Fully integrated into corporate strategy
ESG Reporting	Rare, mostly declarative	Regular, in line with GRI/CSRD/SFDR standards
Regulatory Framework	No mandatory ESG reporting requirement	CSRD, SFDR, Taxonomy Regulation
ESG	Limited offering (e.g., Green	Well-developed product portfolio

Criterion	Republic of North Macedonia	Global Practices (EU/US and others)
Products	Motor Insurance)	
Client Engagement	Low awareness among policyholders	Active ESG campaigns and customer education
Corporate Governance	Basic transparency policies	Advanced systems for ethics, diversity, and inclusion

The presented comparison indicates that the insurance sector in the Republic of North Macedonia remains in the early stage of ESG implementation, in contrast to the developed markets, where sustainability is an essential component of corporate strategies, governance structures, and insurance product design.

DISCUSSION

The results of the conducted research confirm that, both in the short and long term, performance related to environmental, social, and governance (ESG) factors has a significant impact on the liquidity of insurance companies, their level of profitability, operational stability, corporate reputation, client and investor trust, as well as their competitive advantage in an increasingly sustainability-oriented market.

The findings indicate that ESG factors are emerging as an essential strategic orientation for insurance companies and that they play a crucial role in the decision-making process of policyholders when selecting insurance products. Furthermore, the results support contemporary theory and practice, which view ESG not merely as a regulatory or ethical framework but as a concrete business model that generates long-term value for all stakeholders. From the perspective of insurance providers, the integration of environmental, social, and governance dimensions is increasingly associated with enhanced reputation, improved risk management, and the achievement of sustainable growth.

The research findings demonstrate that a considerable number of insurance companies in the Republic of North Macedonia—although still in the development phase—have already begun integrating ESG principles into their strategies and business policies. This trend aligns with global developments and obligations derived from the Principles for Sustainable Insurance (PSI).

In this regard, the discussion leads to recommendations aimed at promoting an ESG-oriented culture within the insurance industry—through regulatory incentives and the inclusion of educational campaigns targeted at policyholders.

CONCLUSION

The ESG concept is experiencing exponential growth, and its significance and impact are becoming increasingly prominent within the global investment landscape. This research confirms that a considerable portion of investors are still at the early stages of integrating environmental, social, and governance factors into their strategies and decision-making processes. This trend highlights the need for systematic education, transparency, and access to high-quality information, which will be essential for the further development and effective implementation of ESG principles. Whereas in the past ESG may have been regarded as a marginal approach or an additional criterion, today its neglect represents a tangible risk—both financial and reputational. ESG is no longer an option but a necessity for sustainable and responsible investing.

These directions encourage insurers to enhance their own ESG performance and to promote a broader green transition in economic and social development.

The findings of the research indicate that the integration of ESG factors and risks within the insurance sector in the Republic of North Macedonia remains at an early stage, with varying levels of maturity among different insurance companies. The results also suggest the need for regulatory and supervisory frameworks to support the incorporation of ESG considerations in the insurance sector. ESG factors should be prioritized in the development of national sustainable finance strategies, with a stronger focus on the contribution of the financial sector to the Sustainable Development Goals (SDGs). As a country aspiring to join the European Union and committed to the 2030 Agenda for Sustainable Development, the Republic of North Macedonia should strategically prioritize these factors within its financial and development policies.

FUTURE RESEARCH

In the future, further progress in ESG-related research is expected across several dimensions, including the following:

Strengthening the theoretical foundation of ESG research.

The theoretical underpinnings of ESG research are both centralized and diverse, predominantly based on *institutional theory* and *stakeholder theory*. At the same time, other studies have drawn from the *natural resource-based view*, *resource dependence theory*, *affect-as-information theory*, *place attachment theory*, *upper echelons theory*, *signaling theory*, *agency theory*, *attribution theory*, *transaction cost theory*, *system justification theory*, and *social identity theory*. However, to date, there is no unified and comprehensive theoretical framework that can systematically explain the internal mechanisms of corporate ESG practices. Hence, as ESG research continues to evolve and mature, further studies are needed to refine and consolidate its theoretical foundation.

Recent developments suggest that ESG research has gradually become more nuanced. In terms of content, it increasingly focuses on the interaction among different dimensions and on internal governance. Nevertheless, there remains room for further advancement. On the one hand, there is a noticeable lack of research addressing the interaction between the *environmental (E)* and *social (S)* dimensions. This may be attributed to the tendency of existing studies to classify the environmental dimension as part of the social one. Consequently, it is rarely examined as an independent component, which is particularly evident in the selection of ESG indices. From a sustainable development perspective, environmental issues are among the most critical concerns, as they form the foundation for the sustainable growth of both the economy and society. Therefore, future research should treat the *environmental (E)* dimension as distinct from the *social (S)* dimension. Furthermore, upcoming studies should aim to explore the relationship between the environmental (E) and social (S) dimensions, enrich the understanding of the interaction between the environmental (E) and governance (G) dimensions, and emphasize the significance and prominence of the environmental (E) aspect within the broader ESG framework.

On the other hand, the *governance (G)* dimension has been a central focus of ESG research, yet few studies have examined its relationship with economic outcomes. Although the factors influencing economic consequences are inherently multidimensional and complex, governance—as a core element of management—remains a key determinant of corporate performance. With the continuing development of the economy and society, governance (G) is becoming an increasingly vital driver of high-quality development. Future research should therefore further investigate the impact of the governance (G) dimension on the economic outcomes of ESG.

Finally, from the perspective of academic institutions, a comprehensive review of ESG research enables a clearer understanding of its context, summarizes the characteristics of previous studies in terms of trends and content, and highlights existing limitations. This

analysis serves as a foundation for proposing several directions for future research and articulating a vision for the continued development of ESG scholarship.

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EQUALITY IN INTERNATIONAL LAW AND THE LEGAL ORDER OF NORTH MACEDONIA WITHIN THE SDGS FRAMEWORKS

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ABSTRACT

Introduction: *The principle of equality is a cornerstone of the rule of law and a prerequisite for safeguarding human rights. This research investigates the extent to which the legal order of the Republic of North Macedonia aligns with international standards on equality and non-discrimination.*

Methods: *A mixed methodological approach was applied, combining normative-legal analysis, comparative-legal method, and doctrinal interpretation. The analysis covered key international legal instruments (Universal Declaration of Human Rights, CEDAW, European Convention on Human Rights, Istanbul Convention) in correlation with national legal acts (Constitution of the Republic of North Macedonia, Law on Prevention and Protection against Discrimination, Law on Equal Opportunities for Women and Men) during the period 2010–2023.*

Results: *The normative-legal analysis indicates a high level of formal harmonization between national legislation and international equality standards. However, the empirical evaluation highlights a considerable implementation gap. Despite the sophistication of the de jure framework, practical enforcement remains limited due to systemic shortcomings.*

Discussion: *The study reveals a paradox between normative compliance and practical effectiveness. Structural constraints within the judiciary, insufficient institutional resources, lack of systematic monitoring, and inconsistent application of international obligations undermine effective protection against discrimination. Bridging this gap requires transforming formal commitments into operational mechanisms to ensure genuine compliance with international equality standards and substantive human rights protection.*

Keywords: Equality; Rule of law; Human rights; Non-discrimination; Judicial system; CEDAW; ECHR; Istanbul Convention; Constitution of North Macedonia; Anti-discrimination law; Legal harmonization

1. INTRODUCTION

The principle of equality represents a cardinal postulate of new contemporary constitutional democracies and is inseparably linked to the concept of the rule of law. In abstract and judicial literature, equality is viewed as a functional principle that guarantees the universality of rights and judicial protection, ensuring that all individuals are treated evenly before the law and institutions (Dworkin 1977; Rawls 1999). In this context, equality is not limited to formal equality and substantive equality, which takes into account the actual

position of individuals and groups in society.In modern decades, the Republic of North Macedonia has worked hard to bring its laws in line with international standardson equality and non-discrimination.

This effort included ratifying the Universal Declaration of Human Rights, the European Convention on Human Rights (ECHR), the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW), and the Istanbul Convention.

However, despite these judicial changes, realistic implementation tranquil faces grievous issues.These include broken institutions, slow judicial processes, and moderate resources for enforcing anti-discrimination policies. This paper intends to examine how the legal framework of the Republic of North Macedonia aligns with international standards on equality and non-discrimination. It will review key judicial acts, case law, and institutional mechanisms. The research will focus on the period from 2010 to 2023, which has seen better judicial and institutional reforms in human rights and the rule of law.

2. THEORETICAL AND METHODOLOGICAL FRAMEWORK

2.1. Theoretical approach

The research is based on the normative-legal theory, which analyzes the structure and content of legal norms in the context of their compliance with international standards. The concept of de jure and de facto equality is applied, where the former describes legal equality, and the latter assesses the practical implementation and effectiveness of legal protection. (Fredman, 2011)

In addition, the paper applies the theory of legal alignment, which analyzes the convergence between international and national law in the processes of harmonization and implementation. Feminist legal theory is also used as an additional framework, especially in the part that relates to gender equality and access to justice for women (MacKinnon, 1987)

2.2. Methodology

The research applies a combined methodological approach that includes the following methods:

1. **Normative legal analysis** – critical examination of substantive and legal provisions in terms of their compliance with international instruments.
2. **Comparative legal method** – comparison with judicial solutions and practice in other countries (Slovenia, Serbia, Croatia, Bulgaria, EU).
3. **DoctrinalAnalysis** – interpretation of pertinent legal literature, scholarly articles and case law.
4. **Empirical analysis** – analysis from reports of institutions (Ombudsman, Commission for Prevention and Protection against Discrimination, European Commission, UN Women).

2.3. Research Objectives

The main objectives of the research are:

• To determine the degree of normative compliance of domestic legislation with international standards;
• To identify gaps and weaknesses in implementation;
• To propose recommendations for improving practical application and institutional coordination.

2.4. Hypotheses

The main hypothesis of the paper is:

Although the legal order of the Republic of North Macedonia is largely formally aligned with international standards for equality and non-discrimination, its practical effectiveness is limited due to systemic institutional weaknesses and insufficient legal implementation.

INTERNATIONAL STANDARDS ON EQUALITY AND NON-DISCRIMINATION

Conceptual foundations of the international legal framework. The principle of equality and the prohibition of discrimination are cardinal values of contemporary international human rights law. These principles have a double nature: on the one hand, they are an expression of the moral-political idealof universal equality of all people, and on the other, they are translated into legally binding normswithin the framework of external treaties and conventions (Donnelly 2003, 45).

In the United Nations system, the concept of equality has been unceasingly developed since the adoption of the Universal Declaration of Human Rights (1948), which in Article 1 establishes that "all human beings are born free and equal in dignityand rights", and Article 2 expands this norm by prohibiting discriminationon any ground, including race, sex, language, religion, political or different opinion, national or social origin, property or different status. The Universal Declaration gave rise to binding covenants – the International Covenant on Civil and Political Rights (ICCPR) and the International Covenant on Economic, Social and Cultural Rights (ICESCR), which further specify the duty of states to provide a legal framework for protection against discriminationand the promotion of equality. These documents establish a comprehensive obligation for states to ensure not only formal, but also substantive equality.

2. European Convention on Human Rights (ECHR)

The European Convention on Human Rights (1950) is one of the most important instruments in the European system for the protection of human rights. Article 14 of the Convention prohibits discrimination in the exercise of the rights guaranteed by the Convention, while **Protocol No. 12 (2000)** extends the prohibition of discrimination to all rights set forth by law.

The European Court of Human Rights (ECtHR) has developed a rich case law that specifies the essence of the principle of equality. **In the case of D.H. and Others v. Czech Republic (2007)**, the Court defined indirect discrimination and emphasized that the state has anpositive obligation to eliminate functional inequality resulting from apparently neutral measures.

This position is particularly relevantfor the Republic of North Macedonia, given that some of the discriminatory effectsin education, employment and access to justice occur not as explicit prohibitions, but as a consequence of general inequalities.

Additionally, **in the case of Opuz v. Turkey (2009)**, the Court established the responsibility of the state for inadequate protection **against gender based violence**, thus establishing the concept of structural responsibility of the state for inaction. This precedent has had a remarkable impact on case law in the region and represents a critical direction for Macedonian institutions in interpreting obligations to protect women from violence.

3.Convention on the Elimination of All Forms of Discrimination against Women (CEDAW)

CEDAW (1979) is the Convention on the Elimination of All Forms of Discrimination against Women, which establishes a system of legal and institutional obligations to eliminate discrimination against women in all areas of public and private life". The Convention introduces **the doctrine of substantive equality**, which goes beyond formal equality,

requiring states to take active measures and policies to achieve real equality between the sexes. (Byrnes and Freeman 2012)

In article 2, states undertake to incorporate the prohibition of discrimination in their constitutions and laws, to provide for sanctions for violations, and to create monitoring institutions. In article 5, it emphasizes the importance of dynamic interpersonal and ethnic patterns of behavior to eliminate stereotypes about the roles of men and women.

The Committee on the Elimination of Discrimination against Women (CEDAW Committee) in its concluding observations on the Republic of North Macedonia (2018) expressed concern about the "insufficient implementation of the legal framework and the limited effectivenesseffectiveness of gender equality institutions", peculiarly with regard to legal protection and access to justice.

The gender perspective in the legal system of North Macedonia remains **preponderantly declarative**, with minimal impact on legal decisions and institutional practice.

4. Istanbul Convention

The Council of Europe Convention on Preventing and Combating Violence against Women and Domestic Violence (Istanbul Convention, 2011) is the most comprehensive instrument for the protection of women from violence and gender based discrimination. It introduces the principle of the four pillars – prevention, protection, prosecution and integrated policies (4Ps model). Article 4 emphasizes that all measures must be implemented without discrimination on any grounds, while Article 5 establishes the state obligation of due diligence obligation– the state's responsibility when it fails to protect victims or prosecute perpetrators.The Republic of North Macedonia ratified the Convention in 2018, and in 2021, several laws were harmonized, including the Law on Preventing and Protecting Against Violence against Women and Domestic Violence. However, according to GREVIO(Group of Experts on Action against Violence against Women and Domestic Violence) reports, the practical implementation remains **limited**, particularly due to **insufficient financial resources**, inadequate institutional coordination, and a lack of **specialised professional staff** (GREVIO, 2022, 12-15)

5. International standards and legal harmonization

In the context of accession to the European Union, North Macedonia is obliged to harmonize its legal frameworkwith the **EU acquis**, which **includes Directive 2000/43/EC**on equal treatment irrespective of racial or ethnic originand **Directive 2006/54/EC** on gender equality in employment and occupation.

Legal harmonization involves not only the transposition, but also the creation of institutional and procedural mechanisms for their implementation. In this process, the **Commission for Prevention and Protection against Discrimination (CPPD)** plays a key role, as it carries the mandate of **independent oversight** in this field.

International standards for equality and non-discrimination constitute a solid standard basis that obliges states to provide effective judicial and institutional protection. In the case of the Republic of North Macedonia, there is a high degree of *de jure* compliance with these standards, but their *de facto* implementation remains a challenge. This gap between the normative framework and practical enforcementwill be examined in detail in the following section.

NATIONAL LEGAL ORDER AND NORMATIVE HARMONIZATION

1. Constitutional and legal framework of the principle of equality

The Constitution of the Republic of North Macedonia (1991, with amendments until 2023) establishes the basis of the constitutional order on the fundamental values **of the rule of law, human freedoms and rights, legal certainty, social justice and equality of citizens.**

Article 9 establishes that:

"Citizens of the Republic of North Macedonia are equal in their freedoms and rights, regardless of gender, race, skin color, national and social origin, political and religious beliefs, property and social status."

This constitutional norm establishes the principle of **formal equality**, which is a legal framework for eliminating discrimination in public and private life. However, the Constitution does not include an explicit definition of **discrimination**, nor does it distinguish between **direct and indirect** discrimination, which leaves **interpretive discretion**in judicial practice.

According to **the Constitutional Court of the Republic of North Macedonia**, the principle of equality does not mean absolute identical treatment, but **requires equality within similar situations** (Decision U.br. 82/2009).This view aligns with the jurisprudence of the **European Court of Human Rights**, which permits differential treatment where **objectively justified** and **proportionate** to a legitimate aim (ECtHR 2007). In practice, this often leads to a restrictive application of the concept of positive discrimination.

2. Law on Prevention and Protection against Discrimination

The most critical general law in this area is the Law on Prevention and Protection against Discrimination (LPPD), originally adopted in 2010, and revised in 2020 for the purpose of harmonization with European directives and recommendations of the Venice Commission.

2.1. Structure and essential principles

The law defines discrimination as "any distinction, exclusion, restriction or preference on any prohibited ground" (Art. 5). Article 6 establishes the types of discrimination: direct, indirect, harassment, victimization and segregation. The novelty in the 2020 judicial amendments is the stated inclusion of gender identity and intersexual orientation as protected grounds, which represents significant progress compared to the old law.

2.2. Institutional mechanisms

The LPDA establishes the Commission for Prevention and Protection against Discrimination (CPPD) as an independent body with the authority to receive complaints, conduct proceedings and issue opinions.

However, the institutional capacity of the Commission remains **limited**due to:

- **insufficient human and financial resources**,
- **lack of investigative powers**, and
- **limited enforceability of its opinions**, which are not binding.

Although the statutory mandate allows for a **broad interpretation** of discrimination, practical implementation is hindered by **low public awareness** and **limited trust** in the effectiveness of available remedies

2.3. Judicial protection

The LPPD enables victims to file **civil lawsuits** to establish discriminatory treatment. In accordance with EU directives, **the burden of proof may be shifted** to the defendant once the claimant presents **prima facie** demonstrating a **plausible presumption** of discrimination (Art. 39; see also European Union 2000; 2000a).

Despite this legal safeguard, analysis of judicial practice (2020–2023) indicates that Macedonian courts **rarely apply** the principle of burden-shifting, instead **requiring the claimant to prove discrimination entirely**, which:

- reduces access to justice, particularly for **vulnerable groups**, and
- contributes to **legal uncertainty** and weak enforcement of equality rights.

3. Law on Equal Opportunities for Women and Men

This law, adopted in 2012 and amended in 2020, operationalizes the essential commitment to gender equality by promoting gender responsive policies and budgeting, as well as establishing coordinating bodies for gender equality in public administration The judicial text contains three key principles:

1. Integration of the gender perspective in all policies and programs;
2. Prohibition of discrimination on the basis of sex and gender;
3. Promotion of equal participation in open and political life.

Despite the standard precision, the application of the law is limited. In the Macedonian legal system, there is a gap between the political rhetoric of gender equality and the genuine distribution of power, which is also reflected in the unostentatious participation of women in the executive and legal branches.

4. Family Law and the Istanbul Convention

In the context of harmonization with the Istanbul Convention, the Family Law was amended in 2021, introducing the terms "gender-based violence" and "victim of domestic violence". In addition, the Law on Prevention and Protection from Violence against Women and Domestic Violence was adopted, which provides a broader institutional framework for protection.

Although the legal framework is comprehensive in theory and content, **practical implementation faces serious obstacles** – an insufficient number of specialized judges, the absence of integrated protocols between the police, the prosecution and social work centers, as well as insufficiently trained staff in municipalities.

5. Compliance with European law

The Republic of North Macedonia, in the process of European integration, has an obligation to harmonize its legislative framework with the law of the European Union (EU acquis).

The European Commission's 2023 report states that "the country has made significant progress in normative compliance, but the implementation of laws and their effective application remain a challenge".

There are positive examples of harmonization of legal terminology, introduction of anti-discrimination training for judges and public prosecutors, as well as the establishment of gender equality networks in institutions. However, the implementation of European directives often faces institutional inertia and limited financial resources.

6. Analysis of standard harmonization

The analysis of the general legal system shows that:

• there is a high degree of formal compliance with international standards;

• but there is a gap between norms and practice, especially in legal interpretation and institutional implementation;

• integration of gender and human rights perspectives into all levels of public policy is needed.

Legal harmonization must be understood as an energizing process that requires continuous education, monitoring and institutional accountability. The general legal framework in the Republic of North Macedonia is mostly aligned with external and European standards for

equality and non-discrimination. However, its effectiveness depends on realistic implementation, institutional coordination and the development of a legal culture that recognizes and addresses the functional nature of discrimination.

IMPLEMENTATION CHALLENGES AND INSTITUTIONAL LIMITATIONS

Although the legal system of the Republic of North Macedonia demonstrates a high level of normative compliance with international standards on equality and non-discrimination, the reality of its implementation reveals serious structural, institutional and cultural obstacles. This section analyses the main factors that limit the effective application of anti-discrimination norms and highlights the paradox between the "de jure" and "de facto" situation in the legal protection of equality.

The legal framework in the field of equality encompasses several institutions with partially overlapping competencies – the Ministry of Labor and Social Policy, the Commission for Prevention and Protection against Discrimination, the Ombudsman, the State Election Commission, the courts and public prosecutors' offices.

This fragmentation of institutional competencies creates a situation in which no single institution has full competence to implement a holistic non-discrimination policy. Institutions operate in parallel, without effective mutual coordination, leading to legal disintegration and duplication of administrative procedures.

This problem is particularly pronounced in procedures for the protection of victims of discrimination, where citizens often move from one institution to another without a real legal outcome.

Despite the formal existence of independent bodies, their resources remain severely limited. The Commission for Prevention and Protection against Discrimination (CPPD) had only 12 employees in 2023, without regional offices, and with a budget that represented less than 0.001% of the state budget.

This fact contradicts the recommendations of the European Commission against Racism and Intolerance (ECRI), according to which anti-discrimination bodies should have "financial and operational autonomy, sufficient human resources and sanctioning powers" (ECRI Report, 2022).

In addition, public sector officials often lack sufficient legal education to recognize indirect discrimination. The lack of specialized training and professional staff results in a formalistic approach to interpreting laws, which undermines their essential function – the protection of human dignity.

4. Case law and limited access to justice

Judicial practice in North Macedonia in the field of anti-discrimination remains very limited. According to available analyses, in the period 2010–2023 **only a small number of court cases** explicitly invoked the Law on Prevention and Protection against Discrimination, and **successful judgments remain exceptionally rare**(OSCE 2022; ECRI 2022).

The courts for the most part do not apply the doctrine of indirect discrimination, but require proof of direct violation, which limits the legal scope of protection. This formalism undermines the idea of substantive equality and it is reduced to a declaratory norm.

Although the Law provides for the possibility of shifting the burden of proof (Art. 39), in practice judges rarely apply this principle. As the OSCE Report (2022) points out, "the courts in North Macedonia largely retain the classical evidentiary regime, contrary to European standards."

This leads to a situation in which victims of discrimination are discouraged from filing lawsuits due to lengthy procedures, financial costs, and uncertain outcomes.

Legal equality cannot be realized in isolation from social values and cultural patterns. North Macedonia, as a society with deep traditional and patriarchal structures, faces limited public awareness of equality-related rights.

In a survey conducted by the Institute for Human Rights (2023), 48% of respondents believe that "women and men already have equal opportunities," while 32% believe that "LGBTQ persons should not seek additional legal protection." These data indicate a deep cultural inertia, which undermines the practical application of anti-discrimination mechanisms.

A transformation of legal awareness is needed through educational and media policies that promote equality as a collective value, rather than as a political condition for European integration.

One of the most significant implementation challenges is the absence of systematic monitoring and statistics on discrimination cases.

Although the Law provides for an annual report by the KSZD, the data are often inconsistent, incomplete or not in line with the reports of the Ombudsman and the courts.

The lack of a centralized database prevents analytical assessment of the effectiveness of laws, which further complicates the process of adopting evidence-based public policies.

In this regard, the OSCE (2023) recommends the establishment of a single register of discrimination cases, integrated with the electronic system for court statistics (AKMIS), as well as regular publication of indicators for gender and social equality.

The implementation of anti-discrimination norms often depends on the political will of the government. Several analyses indicate that the Commission for Prevention and Protection against Discrimination is susceptible to political pressures, especially in the selection of its members.

This phenomenon calls into question the institutional integrity of the body and undermines public trust in its independence. Institutions that are supposed to guarantee the principle of equality are often instrumentalized for political legitimation, rather than for the real protection of human rights.

From a psychological perspective, discrimination is rooted in cognitive prejudices and social stereotypes, which are maintained through educational and media practices.

An interdisciplinary approach requires synergy between law, psychology, sociology and communication to understand and detect the mechanisms of inequality. This approach would enable the development of educational and preventive mechanisms, in order to reduce the need for repressive legal intervention.

The implementation of the principle of equality in North Macedonia faces multifaceted constraints: institutional fragmentation, lack of resources, legal formalism, cultural resistance and political dependence of independent bodies.

Substantial compliance with international standards cannot be achieved without structural reform of the judiciary, continuous education of public servants and strengthening of institutional accountability.

The legal norm is a necessary but not sufficient prerequisite for equality. It is necessary to create an institutional culture of respect for diversity, which implies reform of public administration, development of educational programs on human rights and change of social attitudes towards diversity.

COMPARATIVE ANALYSIS AND RECOMMENDATIONS FOR IMPROVING THE LEGAL AND INSTITUTIONAL FRAMEWORK

Comparative analysis is an essential part of any legal evaluation, as it provides a comparative perspective on the basis of which successful practices and potential weaknesses are identified. In the context of compliance with international equality standards, the Member States of the European Union — in particular Croatia, Slovenia and Bulgaria — represent

relevant comparative models due to their post-socialist legal development, similar institutional structure and transition to the European acquis communautaire. (European Commission 2023, 12–14)

2. Croatia: Institutional integration and proactive policy

Croatia, upon accession to the EU in 2013, established a comprehensive system of protection against discrimination, based on the Law on the Prevention of Discrimination (2008). This law provides for a wide range of protected grounds, an independent equality body (the Equality Commissioner) and active case law. (ECRI 2022, 18)

2.1. Integrated Action Model

The practice in Croatia is characterized by a high degree of coordination between institutions. The Equality Commissioner not only has the authority to receive complaints, but also actively initiates research, public policies and media campaigns.

Compared to North Macedonia, where the Commission for Prevention and Protection against Discrimination acts almost in isolation, the Croatian model demonstrates a functional integration of administrative and preventive functions.

2.2. Judicial interpretation and dynamic approach

Croatian case law in discrimination cases is more advanced, especially in the application of indirect discrimination and shifting the burden of proof.

The judgments of the Higher Administrative Court regularly refer to Art. 14 of the European Convention on Human Rights and Article 21 of the Charter of Fundamental Rights of the EU, which reinforces the Europeanization of the national interpretation.

3. Slovenia: Horizontal application and cultural transformation

Slovenia stands out with an integrative approach to human rights and a high degree of civil society involvement.

The Law on Equal Treatment (ZVarD, 2016) provides for the principle of horizontal application, i.e. an obligation for all public and private entities to ensure non-discriminatory treatment. (Kogovšek 2020, 77).

3.1. Role of the Ombudsman and public dialogue

The Ombudsman in Slovenia has a clearly defined competence to initiate ex officio procedures, as well as to initiate public hearings on systemic cases of discrimination.

In addition to legal protection, the Slovenian model also includes educational policies to promote a culture of equality in schools and public administration.

North Macedonia still retains the reactive nature of institutions, which react only upon complaint, without the capacity for systemic interventions.

The Slovenian approach shows that equality cannot be just a legal concept, but must be a value foundation of public policy.

4. Bulgaria: Judicial review and institutional dependence

Bulgaria presents an example of a paradoxical development: although it has a formally harmonized legal framework with EU directives (Directives 2000/43/EC and 2000/78/EC), practical implementation is limited due to institutional dependence and political pressures. (ECRI 2022, 25).

The Bulgarian Commission for Protection against Discrimination has broad powers, including sanctioning powers, but its political subordination often compromises autonomy.

This situation is similar to the Macedonian one, where the selection of the Commission's members is party-motivated, which undermines public trust and the perception of its independence.

Bulgarian courts rarely engage in a substantive analysis of discrimination, limiting themselves to procedural aspects. This formalism creates legal uncertainty, similar to the Macedonian case law.

5. Comparative overview of equality protection systems in selected countries

Source: Author's analysis based on EC and ECRI reports

Country	Characteristics	Key Strength	Main Weakness
Croatia	**Integrated system and active Ombudsperson**	**Institutional coordination and dynamic case law**	**Limited resources and bureaucracy**
Slovenia	**Horizontal application and educational approach**	**Public awareness and social integration**	**Need for improved statistical data collection**
Bulgaria	**Formal alignment, but political influence persists**	**Strong legal framework**	**Lack of actual independence**
North Macedonia	**Solid normative framework, limited implementation**	**Harmonization with international instruments**	**Institutional fragmentation and formalism**

6. Recommendations for improving the Macedonian system.

6.1. Normative recommendations

1. Clarification of definitions in the Law on Prevention and Protection against Discrimination, peculiarly in the section on indirect and functional discrimination.
2. Introduction of an obligation for enthusiastic measures (affirmative action) in the open sector.
3. Incorporation of international standardsas directly practical norms in case law (Art. 118 Constitution).

6.2. Institutional recommendations

1. Strengthening the capacities of the Commission for Prevention and Protection against Discrimination by increasing the budget and establishing territorial offices.
2. Depoliticisation of the selection of members through a open competition and parliamentary two thirds support.
3. Creation of a general register of discrimination cases, linked to court records and Ombudsman reports.

6.3. Judicial and instructive dimension.

1. Specialized training for judges and prosecutors in the field of human rights and anti-discrimination law.
2. Integration of human rights subjects in university programs and training in open administration.
3. Establishment of a monitoring system and indicators for the effectiveness of anti-discrimination mechanisms.

6.4. Interdisciplinary approach

1. Involvement of sociologists, psychologists, educators and media experts in the process of preventing discrimination.
2. Development of open campaigns that promote a culture of diversity and solidarity.
3. Research on the interpersonal perception of inequality for better adaptation of judicial policies.

7. General guidelines for future alignment with European law

As a candidate country for EU membership, North Macedonia must demonstrate substantial, not just formal, convergence with European law.
It is necessary to:
• establish a permanent mechanism for monitoring the implementation of directives,
• develop European-oriented judicial interpretation, and
• encourage public accountability of institutions in the process of protecting equality.
The comparative review shows that successful models of protection against discrimination are not based solely on normative solutions, but on synergy between the legal framework, institutional practice and cultural change.
For North Macedonia, future progress will depend on whether it succeeds in transforming formal alignment into functional equality, where the law also ensures fairness.

CONCLUSION AND FUTURE PERSPECTIVES

1. General assessment of the research

The research has shown that the legal framework for protection against discrimination in the Republic of North Macedonia is formally aligned with key international and European standards, but that there is a significant disproportion between the norm and its practical application.
This gap between "legal form" and "practice" represents a fundamental challenge for the development of an effective equality system, which is not limited to normative declarativity, but provides real protection and social change.

The main reasons for this situation can be grouped into three categories:
1**. Institutional fragmentation and political dependence** – key bodies for protection against discrimination do not have sufficient autonomy and operational capacity.
2. **Low legal culture and insufficient judicial activity** – courts rarely approach with a proactive interpretation of anti-discrimination norms.
3. **Social inertia and lack of interdisciplinarity** – equality issues are reduced to legal formulas, without including the broader social and educational component.

2. Substantial contributions of the paper

This paper has confirmed the need to connect legal analysis with interdisciplinary approaches, such as sociology, political science and linguistics.
Therefore, the analysis of the language of legal acts, as well as the way the public perceives the concepts of equality and fairness, is a key point for understanding the true scope of anti-discrimination policy.
The interdisciplinary part has shown that linguistic and legal structures are mutually conditioned:

- Terms such as equality, inclusion, diversity are not just symbols, but active categories that shape legal discourse.

Therefore, a modern legal system must develop sensitivity to meanings and context, especially when it comes to protecting vulnerable groups.

3. Comparative perspective

A comparative analysis with the countries of the region (Croatia, Slovenia, Bulgaria) revealed three key factors that influence the success of legal protection against discrimination:

1. **Institutional autonomy and professionalization** – Slovenia and Croatia demonstrate greater independence of equality bodies and a higher level of public trust.
2. **Proactive case law** – the application of European standards by national courts improves the level of legal certainty.
3. **Cultural education and public participation** – successful systems include social support for the values of equality, through education and the media.

In comparison, North Macedonia still treats anti-discrimination as a formal legal obligation, rather than a dynamic process of social transformation.

4. Practical recommendations

4.1. At the institutional level

• To establish a National Council for Equality and Human Rights as a coordinating body between government institutions, the Commission, the Ombudsman and the non-governmental sector.
• To introduce an obligation for annual reporting to the Parliament, with a detailed analysis of the progress in the implementation of anti-discrimination norms.
• To create a simple mechanism for submitting complaints, accessible through digital platforms and in the languages of all communities.

4.2. At the judicial and educational level

• To establish a specialized judicial department for human rights, with judges trained in European practice (according to the Slovenian model).
• To integrate subjects on equality and anti-discrimination into the curricula of the Law and Pedagogical Faculties.
• To organize trainings for journalists and public servants, in order to avoid discriminatory terminology in public speech.

4.3. At the societal level

• To encourage public discourse on a culture of equality, through campaigns that promote social inclusion.
• To establish local forums for equal opportunities, within municipalities, for direct communication between citizens and institutions.
• Develop a national human rights strategy 2026–2030, which will integrate anti-discrimination policy with broader social goals.

5. Future research directions

In the future, attention should be focused on:

• **Empirical research on the effects of laws**, through the analysis of specific cases and statistical data;
• **Linguistic and discursive analyses** of the way institutions communicate with citizens in cases of discrimination;
• **Studying the relationship between digitalization and access to justice**, especially in the context of new technologies and artificial intelligence in administrative procedures.

Such an interdisciplinary approach will enable a more authentic understanding of the law that is constantly adapting to dynamic social conditions.

6. Conclusions

The right to equality is not just a normative declaration, but an ethical and civilizational obligation.

North Macedonia is at a critical juncture between formal compliance and actual implementation.

If it manages to consolidate institutional independence, strengthen legal culture and involve civil society in the creation of public policies, the country can build **an authentic model of European equality** based on the rule of law and human dignity. In this context, **this paper represents a contribution to the theoretical and practical understanding of anti-discrimination**as a key pillar of the modern rule of law— not only as a set of rules, but as a value project of social justice and democratic integrity.

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SNAPLOGIC AUTOMATION AS A CATALYST FOR ETL AND MACHINE LEARNING WORKFLOWS

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ABSTRACT

Introduction: *This study explores the use of SnapLogic automation to modernize Extract, Transform, and Load (ETL) processes and support scalable machine learning (ML) workflows. Traditional ETL pipelines are slowed by manual intervention, inefficiency, and limited scalability.*
Methods: *Our methodology followed an applied research design, focusing on the practical implementation of SnapLogic automation for ETL and machine learning workflows. Automated pipelines were built to handle data preparation, model deployment, and performance monitoring, and were tested with both synthetic and real-world datasets.*
Results: *SnapLogic automation significantly improved efficiency, reduced development time, minimized manual errors, and enabled real-time processing of large, dynamic workloads. Continuous monitoring and automated lifecycle management enhanced system reliability and resilience.*
Discussion*: These findings demonstrate that SnapLogic directly addresses the limitations of traditional ETL by streamlining workflows and bridging the gap between data engineering and ML. While the platform may involve a higher upfront investment, it optimizes long-term costs for large organizations.*

Keywords: Automation, ETL, SnapLogic, Machine Learning, Workflows, Enterprise, AI

1. INTRODUCTION

Addressing modern sustainability challenges requires organizations to adopt data-driven, automated, and collaborative approaches that connect expertise from multiple disciplines. Building resilient infrastructure, fostering innovation, advancing economic productivity, reducing inequality, and protecting the environment all depend on the ability to gather, integrate, and analyze large volumes of diverse data. As environmental, social, and economic systems become more complex and interdependent, efficient data engineering, advanced analytics, and intelligent automation are becoming essential components of sustainable decision-making.

In this broader sustainability landscape, automation platforms such as SnapLogic provide significant value. By streamlining Extract–Transform–Load (ETL) workflows and simplifying the orchestration of machine learning processes, SnapLogic enables organizations to manage complex datasets with greater accuracy, speed, and transparency, (Gour et al. 2010, 786-789) . These capabilities support sustainability efforts such as real-time monitoring of key indicators, predictive modeling for more efficient use of resources, and automated reporting that strengthens accountability and long-term planning.

Sustainable development also requires strong collaboration across fields including environmental science, engineering, public administration, business analytics, and information technologies, (Chalmers, 2003). SnapLogic and the low-code approach lowers technical barriers and supports more inclusive participation, making it easier for multidisciplinary teams to contribute to data-driven sustainability initiatives. Its cloud-ready and scalable architecture further promotes responsible digital transformation and efficient use of technological resources.

Automation of ETL and machine learning workflows is not only a technical improvement but also a strategic enabler for sustainability-oriented digital ecosystems, (Bomma et. al. 2024). SnapLogic capacity to unify data, accelerate analysis, and support collaboration across diverse domains positions it as a catalyst for multidisciplinary efforts toward more intelligent, resilient, and sustainable development. This paper examines how SnapLogic automation strengthens these efforts by improving data accessibility, enhancing analytical capabilities, and supporting innovative solutions across sectors.

2. LITERATURE REVIEW

Research in this area documents the transition from traditional ETL solutions toward more flexible integration platforms capable of supporting real-time data movement, distributed processing, and cloud-based analytics. Highlighting the key benefits such as reduced operational complexity, faster data availability, and improved monitoring capabilities, (Mishra,2020, 69-78).

In sustainability-focused research, achieving long-term social, environmental, and economic goals increasingly depends on high-quality, integrated datasets and reliable analytics pipelines. Studies point to the importance of interdisciplinary collaboration and accessible digital tools that enable data modeling, prediction, and monitoring across domains such as environmental management, resource optimization, and urban systems (Ravi 2025, 52-55), (Kumar et al. 2022, 1292-1297).

Our previous research (Trajkovska et. al. 2023, 212-219), focused primarily on automation and monitoring of ETL processes while distributing data, addressing operational efficiency and integration reliability. This established the foundation for understanding how automated pipelines support large-scale data flows. The current study builds directly on that foundation by extending the focus beyond automation alone. It now explores how SnapLogic ETL automation intersects with machine learning capabilities and how this combined functionality can contribute to broader sustainability-oriented initiatives. Thus, the present research situates ETL automation not only as a technical process but as part of a multidisciplinary digital ecosystem that supports sustainable development.

3. THE CHALLENGE OF UTILIZING INTEGRATION PROCESSES

The effective utilization of integration processes represents a persistent challenge within modern information systems. As organizations increasingly rely on heterogeneous data sources, distributed architectures, and complex workflows, ensuring seamless interoperability becomes essential yet difficult to achieve. Integration processes must address issues such as

data consistency, system compatibility, real-time synchronization, and secure communication across platforms (Zeng, et. al. 2010). Furthermore, the dynamic nature of business requirements demands adaptable and scalable integration strategies capable of evolving alongside technological advancements, (Maréchal, et. al. 1998). These challenges highlight the need for robust methodologies, advanced automation tools, and well-designed governance frameworks to optimize integration efforts and support reliable, end-to-end operational performance.

Within enterprise integration environments, SnapLogic offers a powerful platform for automating data flows, orchestrating services, and enabling seamless connectivity across disparate systems. However, effectively utilizing integration processes in SnapLogic presents several challenges that require careful consideration. The platform's flexibility demands a thorough understanding of pipeline design principles, data transformation patterns, and integration best practices to ensure optimal performance, (Trajkovska et. al. 2023, 212-219). Additionally, managing complex workflows-particularly those involving real-time processing or large-scale data movement-requires robust error handling, monitoring, and governance mechanisms. As organizations scale their digital ecosystems, the ability to design maintainable, efficient, and resilient SnapLogic pipelines becomes crucial. These challenges underscore the importance of strategic planning, technical proficiency, and continuous optimization to fully leverage SnapLogic capabilities in modern integration architectures (Hussain et. al. 2024).

4. METHODS

This study employs a qualitative, exploratory research design aimed at evaluating how SnapLogic automation capabilities support integrated ETL and machine learning workflows within contexts relevant to sustainable development. The design combines conceptual analysis, platform-based workflow demonstration, and comparative evaluation of existing literature.

- **Study Design**

Our methodology was focused on the practical implementation of SnapLogic automation for ETL and machine learning workflows. Automated pipelines were built to handle data preparation, model deployment, and performance monitoring, and were tested with both synthetic and real-world datasets. A multi-method approach was applied to ensure that the study captures both the technical characteristics of SnapLogic and the broader implications for sustainable and collaborative practices, such as sustainability framework mapping – alignment of identified platform functionalities with sustainability-related objectives such as resource optimization, real-time monitoring, data democratization, and multidisciplinary cooperation.

We have worked with dataset that encompassed detailed information related to vehicles as well as associated organizational attributes. The data included variables such as vehicle specifications, pricing structures, discount parameters, model colors, and identification fields, alongside organizational metadata such as company identifiers, employee salaries. This combination of technical and business-level information provided a suitable foundation for constructing and evaluating automated ETL workflows. It also enabled the testing of machine learning capabilities within SnapLogic, as the dataset allowed for diverse transformation tasks, feature engineering processes, and predictive modeling scenarios relevant to real-world operational contexts (Patel,2023,1-5).

- **Data Integration**

Dataset utilized was generated by API trigger for the implementation of the solution. During the preparation of the examples, we have divided the data sets in two parts :

- **Synthetic datasets**, generated to test pipeline behavior under controlled conditions, including volume scaling and error-handling scenarios.
- **Real-world datasets,** selected to validate the practical applicability and performance of the designed workflows in realistic ETL and ML settings.

ETL is a fundamental data integration process used to collect data from multiple sources, convert it into a suitable format, and load it into a target system for analysis or storage, Fig.1. The extraction phase involves retrieving raw data from heterogeneous sources such as databases, APIs, or flat files. During the transformation phase, data is cleaned, normalized, and structured to ensure consistency, quality, and analytical readiness. Finally, in the loading phase, the processed data is delivered to a data warehouse, data lake, or other storage systems for reporting, analytics, or machine learning applications. ETL processes are critical for enabling accurate, timely, and reliable data-driven decision-making (Khan et. al. 2024).

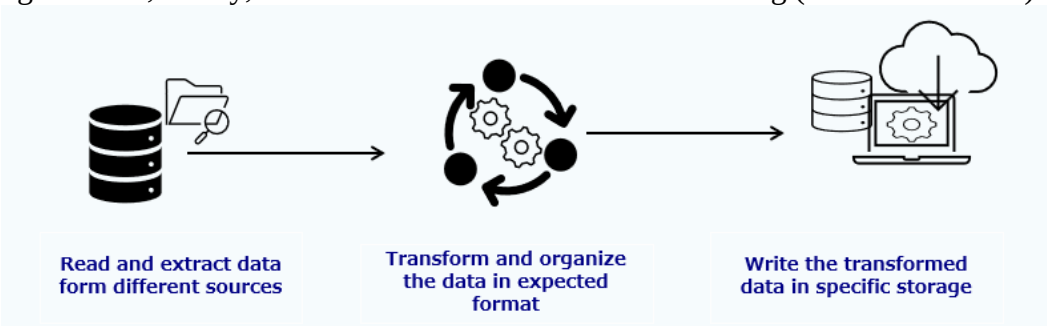

Fig 1. ETL phases overview (Source: Own depiction)

- **Materials and Instruments**

Preparation of the solution relied on the SnapLogic Intelligent Integration Platform, which served as the primary environment for designing, executing, and monitoring automated workflows. The SnapLogic Pipeline Designer was utilized to construct ETL and machine learning pipelines, enabling seamless orchestration of data flows and automation tasks, (Kommera, Reddy,2015). Various data preparation Snaps were integrated to support cleaning, transformation, and feature engineering operations required for model readiness. Machine Learning Snaps were employed for training, scoring, and deploying predictive models within the same unified environment. Additionally, SnapLogic monitoring and dashboard capabilities were used to track execution performance, identify bottlenecks, and evaluate workflow reliability. Complementary tools, including Python-based evaluation scripts and standard performance metrics, were incorporated when needed to validate the outputs of the automated pipelines.

- **Procedure**

The procedures applied in this study were designed to ensure the reliability, accuracy, and consistency of the automated ETL and machine learning workflows developed in SnapLogic. A key component of the procedure involved the implementation of validation and verification rules, which were applied immediately after data ingestion to guarantee that only high-quality and structurally sound data progressed through the pipeline (Clemens-Meyer et. al. 2021). These rules included schema conformity checks, assessments for missing or incomplete

values, verification of identifier consistency, and evaluations of numerical fields to ensure they fell within acceptable operational ranges. By enforcing these rules early in the process, the system was able to automatically detect irregularities and either correct them or isolate problematic records for further inspection.

Data cleaning represented a second critical aspect of the procedure, given the mixed structure of the vehicle and organizational dataset. Cleaning operations were essential for improving the accuracy of transformations and predictive models (Dasu et. al. 2003). Tasks such as standardizing formats, handling missing values, resolving duplicate entries, and normalizing numerical fields ensured that the dataset was coherent and analytically robust. These cleaning steps reduced noise in the data and prevented errors in later stages of the workflow, demonstrating the importance of strong preprocessing practices within automated integration environments.

- **Data Analysis**

Analytical methods included evaluation of model performance (accuracy, precision, error rates) and workflow efficiency (execution time, resource consumption, failure rates). Comparative analyses were conducted between synthetic and real-world executions to determine robustness and generalizability of the automation approach. Qualitative assessment of pipeline maintainability and usability was also incorporated.

5. RESULTS

The implementation and testing of automated ETL and machine learning workflows in SnapLogic demonstrated several key outcomes in terms of efficiency, data quality, and workflow reliability. The pipelines successfully ingested, validated, and transformed both synthetic and real-world datasets containing vehicle and organizational information. Validation and verification rules effectively identified inconsistencies, missing values, and outliers, ensuring that only high-quality data progressed to subsequent transformation and modeling stages. This resulted in clean, standardized, and analytically robust datasets that supported accurate machine learning operations (Côté et. al. 2024).

price	discount	company	model	final_price
4704	1.05	Smith-Walter	Getz	4480
1098	1.05	Moore-Hagenes	Fusion	1046
30	1.05	Stiedemann, Jacob...	Note	29
21395	1.05	Feeney Group	Elantra	20376
1098	1.05	Harvey, Parisian an...	Sportage	1046
25089	1.05	Halvorson, Fay and ...	X5 E70	23894
5331	1.05	Mertz, Abshire and ...	C 180	5077
8154	1.05	Kreiger LLC	Vectra B	7766

Fig 2. Dataset examples (Source: Own depiction)

Automated data preparation tasks including normalization, deduplication, and feature engineering, were executed seamlessly within the SnapLogic platform, reducing manual intervention and minimizing the potential for human error, Fig. 2.

The integration of machine learning Snaps enabled end-to-end automation of model training, deployment, and scoring, providing real-time insights from the processed data, Fig. 3. Performance monitoring and logging features allowed continuous observation of pipeline execution, facilitating rapid identification of bottlenecks and system inefficiencies.

Fig 3. Automation of ETL process (Source: Own depiction)

Comparisons between synthetic and real-world datasets highlighted the scalability and adaptability of SnapLogic workflows. Pipelines maintained stable execution even under varying data volumes and complexity, demonstrating robustness in handling heterogeneous datasets. Furthermore, the low-code environment facilitated workflow adjustments and multidisciplinary collaboration, allowing non-technical users to engage in data preparation and analysis processes effectively.

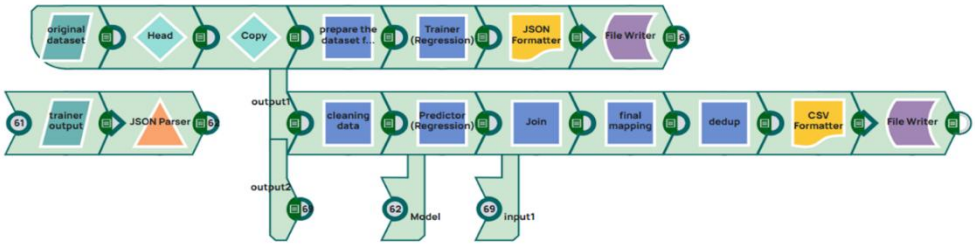

Fig 4. Machine Learning Workflow in SnapLogic (Source: Own depiction)

The machine learning component of the workflow employed a Random Forest Regression model to generate predictive insights based on the numerical and categorical attributes contained in the dataset (Fig. 4). After the data was cleaned, validated, and transformed, the selected features-such as vehicle model, company characteristics, and price-related variables were used to train the regression algorithm. Random Forest was selected due to its ability to capture nonlinear relationships, handle complex feature interactions, and provide higher predictive stability compared to single-model approaches. Once trained, the model produced predicted price values for each record, demonstrating how SnapLogic integrated machine learning capabilities can operationalize advanced regression techniques within automated ETL workflows, Fig.5 .


```
▼ [
  ▼ {
    "readable": "RandomForest\n\nBagging with 100 iterations and base learner\n\nweka.classifiers.trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1 -depth 15 -do-not-check-capabilities",
    "metadata": "rO0ABXNyABN3ZWthLmNvcmUuSW5zdGFuY2Vz/7SlkzRlqaQCAAZJAAxtX0NsYXNzSW5kZXhJAAdtX0xpbmVzTAAMbV9BdHRyaWJ1dGVzdAAVTGphdmEvdXRpbC9BcnJheUxpc3Q7TAALbV9Jb
    "model": "rO0ABXNyACN3ZWthLmNsYXNzaWZpZXJzLnRyZWVzLlJhbmRvbUZvcmVzdA9/z5TVRjBaAgABWgAcbV9jb21wdXRlQXR0cmlidXRlSW1wb3J0YW5jZXhyAB13ZWthLmNsYXNzaWZpZXJzLm1ldGEuQm
  }
]
```


Fig 5. Model description in SnapLogic (Source: Own depiction)

Additionally, it was applied to the dataset to compute predicted prices for each vehicle entry. The table illustrates a comparison between the actual price values and the predicted_price generated by the regression model, shown below in Fig. 5. These predictions reflect the model's attempt to estimate vehicle pricing patterns based on learned relationships within the data. The output confirms that SnapLogic integrated machine learning capabilities

can execute end-to-end prediction tasks directly within automated ETL workflows, enabling real-time scoring and analytical insight generation.

Preview Type
Table

company_name	model	price	predicted_price
Adams, Dibbert and...	Sonata	1792	2755.0464
Beer Inc	Sonata	1792	4061.482933333333
Hoppe, Bins and Go...	Santa FE	46378	40850.373599999...
Leffler-Monahan	FIT	7766	8732.311666666666
Kuphal-Leffler	Avalanche	5227	6928.725199999999
Smitham Group	X5 E70	23894	24059.5454
Cartwright LLC	CX-5	49282	38137.3549999999...
Mertz, Abshire and ...	Caddy	7467	7951.2069999999...
Hintz, Spinka and C...	Optima	597	1478.61979999999...
Grimes-Morissette	Cruze	14336	14904.0538000000...
Leffler-Monahan	Kizashi	7467	7875.0780666666...
Schaden Group	Fusion	821	2055.4871714285714

Fig 6. Predicted price based on the data (Source: Own depiction)

The results indicate that SnapLogic serves as a practical and effective platform for combining ETL automation with machine learning orchestration. The integration of these capabilities within a single platform not only enhances operational efficiency but also provides a scalable foundation for supporting sustainability-oriented analytics, enabling organizations to derive actionable insights and implement data-driven strategies with minimal overhead.

6. DISCUSSION

The findings from the implementation of automated ETL and machine learning workflows in SnapLogic demonstrate the platform's capacity to enhance data processing efficiency, improve workflow reliability, and support multidisciplinary collaboration. The successful ingestion, validation, and transformation of both synthetic and real-world datasets highlight the effectiveness of integrated validation and data cleaning procedures, confirming the importance of these steps in maintaining high-quality data for analytical and predictive tasks.

The results indicate that SnapLogic low-code environment facilitates collaboration across technical and non-technical team members, allowing domain experts to participate in data preparation and model deployment. This feature aligns closely with the goals of multidisciplinary projects, where effective collaboration between data engineers, analysts, and domain specialists is essential for deriving actionable insights. Furthermore, the automated orchestration of machine learning workflows within the same platform demonstrates the potential for end-to-end pipeline efficiency, reducing manual intervention and minimizing the risk of errors while maintaining consistent performance across datasets of varying size and complexity.

From a sustainability perspective, the integration of ETL automation with machine learning capabilities presents opportunities for more informed and responsive decision-making. Automated pipelines enable real-time monitoring, predictive modeling, and resource optimization, which are critical components for organizations pursuing data-driven sustainability initiatives. By reducing time and effort required for data processing and model execution, SnapLogic contributes to operational efficiency while enabling the rapid application of insights in sustainability-focused domains, such as environmental monitoring, energy management, or supply chain optimization, Fig.7. The Monitor interface allows users to track pipeline performance metrics such as execution duration, throughput, memory consumption, and data processing volumes. It also enables real-time observation of task status, including successful executions, warnings, and failure events. Additionally, users can monitor Groundplex health, resource utilization, and node availability to ensure stable

operational performance. Detailed logs and execution histories support troubleshooting, auditing, and optimization of workflows, making monitoring a critical component for maintaining reliable and efficient automation within the SnapLogic platform.

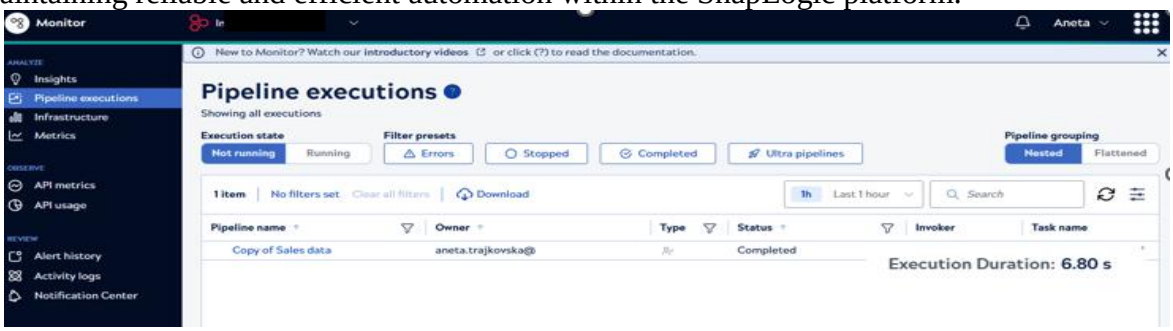

Fig 7. Monitoring workflows execution in SnapLogic (Source: Own depiction)

Despite the demonstrated benefits, several limitations were identified during the study. SnapLogic machine learning capabilities, while efficient for lightweight and moderately sized models, are not ideal for large-scale model training that requires GPU acceleration or distributed cluster compute, which may restrict its applicability in highly complex analytical environments. Pipeline performance was also found to be dependent on the configuration and capacity of the Groundplex infrastructure, meaning that execution speed and stability can vary significantly based on organizational setup, available compute resources, and parallel processing configurations. Furthermore, the full functionality of ETL and machine learning workflows is dependent on specific SnapPack licensing, which may limit access to advanced features if the required components are not purchased. These constraints highlight the need for careful planning, appropriate infrastructure provisioning, and licensing considerations when deploying SnapLogic for enterprise-level automation and analytics. This makes the platform more accessible and cost-effective for large enterprises with long-term integration strategies, while smaller organizations may struggle to justify the upfront expenditure.

Discussion emphasizes that SnapLogic serves not only as a technical tool for ETL and machine learning automation but also as a strategic enabler for multidisciplinary, sustainability-oriented projects. The platform combination of automation, machine learning integration, and user-friendly interface allows organizations to streamline workflows, foster collaboration, and implement data-driven strategies effectively. These findings build directly on prior research focused solely on ETL automation, expanding the scope to include machine learning orchestration and the broader implications for sustainable development initiatives.

7. CONCLUSION

This study examined the application of SnapLogic automation as a catalyst for ETL and machine learning workflows, with a focus on its potential to support multidisciplinary and sustainability-oriented initiatives. The findings demonstrate that SnapLogic enables seamless integration, data preparation, and model orchestration within a single platform, reducing manual effort, enhancing workflow reliability, and improving overall operational efficiency. Validation and data cleaning procedures were shown to be critical in maintaining data quality, while automated ML pipelines provided reproducible, scalable, and actionable insights from both synthetic and real-world datasets.

The research highlights the platform's capacity to facilitate collaboration between technical and non-technical team members, making it a valuable tool for multidisciplinary projects where decision-making is essential. Furthermore, the integration of automation with

machine learning offers tangible benefits for sustainability-focused applications, including real-time monitoring, predictive modeling, and optimized resource management. These capabilities position SnapLogic not only as a technical solution but also as a strategic enabler for organizations aiming to implement intelligent, sustainable, and data-driven processes.

Building on prior work focused solely on ETL automation, this study extends the understanding of SnapLogic role in orchestrating machine learning workflows and supporting sustainability initiatives. Future research could explore the performance of such pipelines in large-scale enterprise environments, investigate additional use cases in environmental and social domains, and develop standardized metrics for evaluating the platform's contribution to sustainable development goals. Also, extending the analytical framework to enhance its scalability and integration of advanced ML and predictive analytics.

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NGOs AND HUMAN SECURITY: CONTRIBUTION TO THE IMPLEMENTATION OF THE 2030 AGENDA IN NORTH MACEDONIA

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ABSTRACT

In North Macedonia, Non-Governmental Organizations (NGOs) play an important role by addressing specific Sustainable Development Goals (SDGs) themes that prioritize human security. This study aims to answer the research question: How engaged are NGOs in North Macedonia in fulfilling the SDGs that touch on human security themes? The hypothesis is that NGOs in North Macedonia are moderately engaged in achieving the SDGs due to limited information and financial opportunities.The methodology used in our scientific paper is based on a qualitative analysis of United Nations reports on the SDGs in North Macedonia, the Government of North Macedonia's strategic documents, and NGOs' reports on their engagement with the SDGs.Some NGOs in North Macedonia are engaged in achieving the SDGs, with a special emphasis on human security. It is expected that further analysis will establish that NGOs play an important role in human security, as they operate at the local level and can more easily foster regional cooperation that advances the SDGs with a human security character.NGOs in North Macedonia are an important factor in connecting sustainable development and human security by engaging in work aligned with the SDGs across various themes. Their efforts to fulfill the SDGs with a human security character are constrained by the limited support they receive from institutions and donors. Strengthening capacities, creating new opportunities, and providing greater institutional and financial support are essential to their commitment to fulfilling the SDGs.

Keywords: Non-Governmental Organizations, Sustainable Development Goals, Human Security, Agenda 2030, North Macedonia

INTRODUCTION

Human security is closely related to people's sense of concern for job security, financial security, health security, environmental security, and security from crime. According to the 1994 UNDP (United Nations Development Programme) Human Development Report, human security is a comprehensive concept for people everywhere in the world because the above-mentioned threats are common. Based on the terminology of "common", nations must react in the same way in the fight against these threats (UNDP, 1994). In the 2030 Agenda for Sustainable Development, the human security approach is closely linked to the achievement of most of the SDGs, using NGOs as key tools in their

completion. In this case, we can emphasize the important role that NGOs have in achieving the SDGs with an emphasis on human security by contributing to several themes in particular such as education, gender equality, ecological stability and institutional inclusiveness (United Nations, 2015). For countries like North Macedonia, the realization of the SDGs in the context of human security by putting the role of NGOs into function for the needs of the community becomes an important factor.

The research question that guided us during the scientific paper is "How engaged are NGOs in North Macedonia in fulfilling the SDGs that affect human security topics?". Civil society in North Macedonia is organized through NGOs and actively contributes to various activities. Most of the fields of action are closely related to the concept of human security. But this connection is not strong in practice due to the lack of communication and lack of cooperation that NGOs have with national structures for fulfilling the SDGs. Therefore, the hypothesis of this scientific paper is that "NGOs in North Macedonia are moderately engaged in achieving the SDGs due to lack of information and limited financial opportunities".

The objective of the scientific paper begins with an analysis of the role and activity of NGOs in key areas of human security. The paper aims to identify institutional gaps that limit their impact on human security. It assesses the involvement of NGOs in the implementation of the 2030 Agenda and provides practical recommendations for more qualitative results. The importance of this scientific paper lies in emphasizing the role of NGOs in the development of human security by contributing to the sustainable development of North Macedonia.

THEORETICAL BACKGROUND

According to researcher Shahrbanou Tadjbakhsh, the concept of human security deals with the ability to identify threats, to avoid them and to mitigate their effects when they occur. The use of the term "human security" includes two directions: one is that the notion of security now goes beyond security in the traditional sense of "physical security" and the other that people's lives must be guaranteed through "social security" against human threats. Therefore, new actors appear on the international scene that leave aside the activity of traditional security by focusing on human security such as: international organizations, international corporations, NGOs and other non-state entities (Tadjbakhsh, 2005).

The SDGs are 17 global goals designed to end poverty, protect the planet, and ensure that all people enjoy prosperity and peace. The SDGs address various social, economic, health, education, environmental, and international issues. Human security is therefore considered an aspect that enriches and complements the mechanisms for achieving the SDGs (Olaniyan et al, 2020). According to economist Hickel, one of the main advocates for the fulfillment of the SDGs are NGOs and sustainable development policies, using their expertise, networks, and resources to raise awareness, mobilize support, and promote the adoption of ambitious goals and commitments. Their advocacy efforts have not only been instrumental in generating political will, but also in ensuring that the voices of marginalized and vulnerable groups are represented in policy discussions (Hickel, 2016).

Civil society in North Macedonia is characterized by limited breadth and depth of participation in civil life. NGOs have quality communication, coordination and cooperation among themselves. Also, within the framework of structural organization, NGOs are well organized by respecting legal acts and norms. As for inter-institutional cooperation, work still needs to be done. In North Macedonia, only a small part of NGOs participate in activities due to the lack of communication, coordination and cooperation with decision-making institutions (Kelmend Zajazi et al, 2008). Based on the NGO Sustainability Index recently conducted in 2021 in North Macedonia by the United States Agency for International Development (USAID), we find that funding constraints, political pressures, weak consultations between NGOs and public institutions, and weak institutional cooperation create a gap between local-

level engagement and integration into national-level policies, including the SDGs (USAID, 2022).

METHODS

This study uses a qualitative approach mainly because it fits better with what the research is trying to understand. Instead of relying on numerical data, the analysis here relies on documents that talk about public policies, the role of NGOs and how they work in the field. The materials were selected by looking at the reports of state institutions, international organizations and the civil sector itself, as they provide a broader view of what is happening in different areas such as education, gender equality, the environment and governance. The idea was to create a balanced picture, not perfect, but sufficient to understand where NGOs are positioned within the 2030 Agenda.

The analysis of the documents was done by reading the materials several times and noting themes that were repeated most often. These themes were then compared between the reports to see where they matched and where differences emerged. From this it was seen that NGOs contribute in several areas, but also have clear challenges, especially when it comes to cooperation with institutions and the lack of sustainable resources. This way of working, although not strictly formalized, offered a more natural and honest understanding of the current situation.

RESULTS

In North Macedonia, based on official statistics from the Central Registry of North Macedonia, there are 16,466 NGOs operating. Of the total number, 9,195 are active NGOs, while 7,271 are passive. This distribution shows a numerically large civil sector, but with different levels of activity and functionality, suggesting that the real capacities of organizations are uneven and depend on their resources, structure and practical commitment (Central Registry of North Macedonia).

The analysis of the documents shows that the activities of NGOs in North Macedonia are focused on several areas that are directly related to human security. In education programs, many organizations work with young people, provide support to the most vulnerable communities, and develop non-formal education initiatives, which are also highlighted in the annual reports of the United Nations (UNCT 2021). A similar pattern is seen in the area of gender equality, where NGOs provide support services and interventions against gender-based violence, a topic also highlighted by UN Women (2022). In the environment, organizations carry out anti-pollution campaigns and climate initiatives, which are mentioned in the UN country assessments (UNCT 2022). These data create a clear picture that the civil sector has a broad role in the social and environmental dimensions of human security.

However, the findings suggest that this multifaceted work on the ground is not fully reflected in official sustainable development documents. The 2020 National Voluntary Report mentions "limited" participation of NGOs in consultations and reporting processes (Government of North Macedonia 2020). UNDP reports also note that civil society contributions are rarely systematically included in national SDG policies (UNDP 2020). This creates a gap between the practical activities of the civil society sector and the institutional structures of policy-making. Simply put, their work has local impact, but does not always find its place at the national level.

The structural barriers that influence this lack of coordination are also clearly evident in the documents reviewed. Many organizations operate with unstable funding and depend on short-term projects, which is clearly highlighted in the CSO Sustainability Index (USAID 2021, 2022). Some reports mention that cooperation with institutions remains sporadic and without regular consultative mechanisms, which makes it difficult to include them in policy-making processes (Donevska 2018; Markovik 2018). Also, some organizations lack the

necessary capacities for data collection and monitoring of results, which reduces their ability to contribute to official reporting on the SDGs. These obstacles are not unique to North Macedonia, but in the country's context they remain particularly visible.

Despite the challenges, some positive trends are observed in the literature. Youth activism is growing, especially on issues related to human rights and environmental protection (UNCT 2022). The use of digital platforms has offered new forms of engagement and interaction with citizens, a development reported as positive by UNDP (2021). In some cases, civil society organizations are experimenting with alternative forms of financing, such as social entrepreneurship and crowdfunding, which USAID (2022) presents as potential opportunities for increasing sustainability. These developments provide signals that the civil sector is adapting to structural challenges and finding new ways of acting.

Another important outcome relates to the opportunities for greater involvement of NGOs in SDG processes. UN reports indicate that civil society representation in the National SDG Council can serve as a step towards more regular cooperation between institutions and the civil sector (UNCT 2021). NGOs have the capacity to provide valuable information from the local level, which institutions often do not collect or have the opportunity to monitor. The documents suggest that, with better coordination and consultation mechanisms, their role in promoting human security and achieving the SDGs can become much more inclusive and visible in public policies.

CONCLUSIONS

When putting all the findings together, it becomes quite clear that NGOs in North Macedonia play a steady and often necessary role in different areas tied to human security, even if this role is not always fully visible in national planning documents. A lot of their work happens quietly at the community level, where organizations step in when public services are limited or slow to respond. This is noticeable in education, gender support, environmental actions and different forms of community assistance. Their impact is real on the ground, but it does not always make its way cleanly into the SDG structures at the national level, and that gap is visible throughout the documents reviewed.

Part of this disconnect seems to come from very practical issues. Many NGOs depend on short-term projects that don't allow them to plan ahead, and cooperation with institutions is sometimes irregular: sometimes it works well, sometimes it's more formal than meaningful. Collecting and organizing data is also a challenge for a lot of organizations, simply because they do not always have the staff, time or tools to document everything consistently. These limitations make it harder for their work to be recognized or reflected in national reporting, even when they are doing valuable things locally.

Still, there are signs of positive movement. Young people are becoming more involved, especially in topics like the environment and human rights, and digital tools seem to be helping NGOs communicate and organize more effectively. A few organizations are trying new funding methods, like small social enterprise activities or community fundraising, which may help them rely less on traditional donor cycles. These changes are not dramatic yet, but they show that the sector is adapting and looking for new ways to stay active.

Overall, the study suggests that NGOs do contribute meaningfully to human security in the country, but the connection between their local work and national sustainable development strategies is not strong enough. More stable funding, clearer cooperation with institutions and better opportunities for civil society to join policy discussions would help bridge that distance. If these gaps were reduced, the work happening at the community level would have a better chance of influencing long-term development goals and supporting the country's progress toward the 2030 Agenda.

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ECOLOGICAL STATUS ASSESSMENT OF LAKE PRESPA BASED ON THE MACROZOOBENTHOS FAUNA

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ABSTRACT

Introduction: *Lake Prespa, a transboundary freshwater ecosystem of high ecological value, is increasingly affected by anthropogenic pressures and fluctuating water levels. This study assesses the ecological status of its littoral zone (North Macedonian side) based on the composition, diversity and distribution of macrozoobenthic communities.*
Methods and results: *Sampling was carried out in autumn 2022 at three sites: Oteshevo, Nakolec and Krani. The research was conducted using standard limnological methods and in accordance with the EU Directive. Samples were collected using a van Ven grab (225 cm^2) at various depths and habitats, using vertical transects extending to the limit of macrophytic vegetation.A total of eleven species from seven systematic groups were registered: Oligochaeta, Hirudinea, Gastropoda, Bivalvia, Amphipoda, Isopoda and Insecta. Nakolec and Krani recorded higher diversity (8 species each), while Oteshevo had only 5. Macrozoobenthos density ranged from 1250 ind/m² (Oteshevo) to 3250 ind/m² (Nakolec), with* Dreissena carinata *peaking at 1875 ind/m² at 2 m depth in Nakolec. A clear decline in biodiversity with depth was observed.*
Discussion: *The results indicate that the invertebrate biodiversity decreases with depth, likely due to increasing sediment uniformity and greater stability of environmental factors with depth. Continued monitoring is recommended for long-term ecological assessment.*

Keywords: macrozoobenthos, biodiversity, ecological status, Lake Prespa, anthropogenic impact.

INTRODUCTION

Benthic macroinvertebrate community structure is most effectively assessed through biodiversity metrics, which encompass both species richness and the relative abundance of taxa within a given assemblage (Rosenberg & Resh 1993; Bonada et al. 2006).

In lake ecosystems, benthic communities are highly responsive to environmental gradients and anthropogenic pressures, with changes typically manifesting in the qualitative and quantitative composition of macrozoobenthos populations (Johnson et al. 2006). This study focused on evaluating structural indices—such as species richness, diversity, and evenness—of benthic fauna across distinct habitats within the littoral zone of Lake Prespa. Sampling was conducted at three littoral localities in the Macedonian part of the lake: Oteshevo, Nakolec, and Krani. These sites were selected based on habitat heterogeneity and exposure to varying degrees of anthropogenic influence.

The research contributes to long-term ecological monitoring and conservation efforts, particularly under conditions of climate variability and nutrient enrichment, which pose increasing threats to Lake Prespa. By analyzing benthic community structure and biodiversity patterns, the study provides critical insights into the ecological integrity of Lake Prespa and supports the development of bioindicator-based management strategies tailored to the lake's unique limnological characteristics.

LITERATURE REVIEW

Earlier studies (2020–2023) showed a strong decline in macrozoobenthos diversity and abundance in Lake Prespa due to water-level fluctuations (Trajanovski et al. 2023). Research from 2023 confirmed this trend across all surveyed localities and again identified *Dreissena carinata* as the dominant species (Trajanovski et al. 2024; Budzakoska-Gjoreska et al. 2024; 2024a). These findings highlight global warming and changes in trophic status as key factors driving species shifts in the lake.

There is limited information on how benthic communities differ across littoral habitats in Lake Prespa, especially among the Macedonian sites Oteshevo, Nakolec and Krani. This study fills that gap by comparing species richness, diversity and evenness across these localities.

METHODS

The field research took place in three localities (Oteshevo, Nakolec and Krani) which, according to previous research, are characterised by varying intensities of anthropogenic pressure and changes in ecological status. The study was designed as a comparative ecological assessment of macrozoobenthic community structures across three distinct littoral habitats in Lake Prespa.The research was conducted using standard limnological methods (Lind 1985; Wetzel 1975; Wetzel & Likens 1979) and in accordance with the EU Directive. Samples were collected using a van Ven grab (225 cm^2) from various depths and habitats with the method of vertical transects extending to the limit of macrophytic vegetation in Lake Prespa. The density values refer to the average density of individuals from two samples per unit surface area (m^2). Macrozobenthos species were determined using keys according to the following authors: Hrabe (1941); Šapkarev (1975); Barnes (1980); Lukin (1976); Lind (1985); Brinkhurst& Jamieson (1978); Hadčišče (1953; 1958 II, 1958 III); Radoman (1983), Kerovec (1986), Kellogg (1994). The determination was done to the level of species. The processed material was preserved in 96% ethyl alcohol, labeled and stored in plastic vials.

To evaluate biodiversity and ecological status, several structural indices were calculated, including species richness, diversity, and evenness.

1) *Index of Species Richness*, according to Margalef (1958), allows the measurement of species richness and the presence of each species in the community, where *n* is the total number of organisms (individuals) of each species, while *N* represents the total number of organisms (individuals) of all macrozoobenthos species in the sample.

$$d = \frac{\sum n(n-1)}{N(N-1)}$$

2) The diversity index (H') according the Shannon-Wiener's formula takes into accountspecies diversityofall species in the community. *S* represents the number of species in the benthic macrozoobenthos communities; *N* is the total number of individuals in the sample, while n_i is the total number of individuals of each macrozoobenthos species.

$$H' = -\sum_{i=1}^{S}\left(\frac{n_i}{N}\right)\ln\left(\frac{n_i}{N}\right)$$ where N= Σ $n_i$or H= - sum (pi·ln(pi)

3) The index of evenness $J_{(e)}$ is calculated according to the formula of Pielou (1966). Using species richness (S) and Shanon-Wiener index (H') we can calculate how similar the density of different types of macrozoobenthos community is. When all registered species have similar densities, the value of the index of evenness equals1, and when species have different densities (some rareand some frequent) the index`s value increases.

$$J_{(e)} = \frac{H'}{\ln S}$$

ASPT (Average Score Per Taxon) represents the average tolerance score of all taxa within the community and is calculated by dividing the BMWP (Table-6 overleaf) by the number of families represented in the sample (Mandaville 2002).

RESULTS

During the field activities at the beginning of December 2022, the qualitative and quantitative composition of the benthic fauna at the Oteshevo locality was assessed. A total of six species belonging to five classes of bottom fauna (Oligochaeta, Hiridinea, Gastropoda, Amphipoda and Insecta) were registered in the samples (Tab.1). The species representing these five classes are indicators of increased water trophic level, indicating the presence of organic pollution in the water. The highest biodiversity, with four species, was recorded at a depth of 2 meters on a muddy bottom with shells and macrophyte vegetation. In terms of density, the highest was found in the population of *Chironomus plumosus* with 375 ind/m^2.

Table 1. Composition and density of bottom fauna in Otesevo (**December** 2022)

Locality Otesevo				
Depth (m)	**Bottom facies**	**Class**	**Species of macrozoobenthos**	**Density (ind/m^2)**
2	Mud with shells and macrophytes (40:50:10%)	Oligochaeta	*Tubifex tubifex*	200
		Gastropoda	*Pyrgohydrobia prespaensis*	25
		Amphipoda	*Gammarus triacanthus prespensis*	175
		Insecta	*Chironomus plumosus*	375
5	Mud withDreissena shells (40:60%)	Oligochaeta	*Tubifex tubifex*	50
		Hirudinea	*Erpobdella octoculata*	25
		Insecta	*Chironomus plumosus*	325
10	Mud with shells (95:5%)	Insecta	*Chironomus plumosus*	75

Table 2. Composition and density of bottom fauna in Nakolec (November 2022)

Locality Nakolec				
Depth (m)	**Bottom facies**	**Class**	**Species of macrozoobenthos**	**Density (ind/m^2)**
2	Mud with shells and macrophyte vegetation	Oligochaeta	*Pothamotrix hammoniensis*	175
			Limnodrilus hoffmeisteri	25
		Bivalvia	*Dreissena carinata*	1875
		Hirudinea	*Erpobdella octoculata*	25
		Amphipoda	*Gammarus triacanthus prespensis*	575
		Insecta	*Chironomus plumosus*	50
5	Mud with shells (1:1)	Oligochaeta	*Limnodrilus hoffmeisteri*	100
			Eiseniella tetraedra	125
		Gastropoda	*Valvata piscinalis*	25
		Bivalvia	*Dreissena carinata*	100
		Amphipoda	*Gammarus triacanthus prespensis*	25
		Insecta	*Chironomus plumosus*	75
10	Mud (90% mud, 10% shells of Dreissena)	Oligochaeta	*Pothamotrix hammoniensis*	50
		Insecta	*Chironomus plumosus*	25

The bottom fauna at the Nakolec locality was represented by eight taxa from six classes of organisms: Oligochaeta, Gastropoda, Bivalvia, Amphipoda, Hirudinea and Insecta. Although the bottom of this profile along the transect showed a fair degree of uniformity (mud and shell facies), the distribution of species was not uniform. Thus, the highest density of organisms was observed at a depth of 2 meters, on a silty facies of crushed shells and snails with vegetation. Six species from five classes were registered on this facies. Quantitatively, the species *Dreissena carinata* was present with the highest density - 1875 ind/m^2.

Table 3. Composition and density of bottom fauna in Krani (November 2022)

Locality Krani				
Depth (m)	**Bottom facies**	**Class**	**Species of macrozoobenthos**	**Density (ind/m^2)**
2	Mud with shells	Oligochaeta	*Pothamotrix hammoniensis*	150
			Limnodrilus hoffmeisteri	25
		Amphipoda	*Gammarus triacanthus prespensis*	25
		Insecta	*Chironomus plumosus*	50
5	Mud with shells (50-50 %)	Oligochaeta	*Limnodrilus hoffmeisteri*	75
		Bivalvia	*Dreissena carinata*	925
		Amphipoda	*Gammarus triacanthusprespensis*	50
		Isopoda	*Asellus aquaticus*	75
		Insecta	*Chironomus plumosus*	50
10.5	Mud with shells (80-20 %)	Oligochaeta	*Pothamotrix hammoniensis*	150
		Gastropoda	*Valvata piscinalis*	25
			Pyrgohydrobia prespensis	25
		Amphipoda	*Gammarus triacanthus prespensis*	25
		Insecta	*Chironomus plumosus*	75

During the autumn campaign, the bottom fauna at the Krani locality was represented by eight taxa from six groups of organisms: Oligochaeta, Gastropoda, Bivalvia, Amphipoda, Isopoda and Insecta. The highest density of organisms was recorded at a depth of 5 meters on a silty facies with shells, where five species were determinate. The most abundant species was *Dreissena carinata*, with a population density of 925 ind/m².

A total of eleven species from seven systematic groups were registered: Oligochaeta, Hirudinea, Gastropoda, Bivalvia, Amphipoda, Isopoda and Insecta (Table 4).

Table 4:**List of macrozoobenthos species composition in Prespa Lake** (**autumn** 2022)

Class	**Species**
Oligochaeta	*Pothamotrix hammoniensis*
	Limnodrilus hoffmeisteri
	Tubifex tubifex
	Eiseniella tetraedra
Bivalvia	*Dreissena carinata*
Hirudinea	*Erpobdella octoculata*
Amphipoda	*Gammarus triacanthus prespensis*
Insecta	*Chironomus plumosus*
Gastropoda	*Pyrgohydrobia prespaensis*
	Valvata piscinalis
Isopoda	*Asellus aquaticus*

Table 5 presents the ecological status of the sampling sites as assessed by traditional diversity indices. While the Pielou evenness and Simpson diversity indices suggest a wide range of environmental conditions—from very good to poor—their outputs appear inconsistent with other key indicators of ecological degradation.

Table 5. Ecological status of localities according to the indices (autumn 2022)
* Red: very heavily polluted waters; Orange: heavily polluted waters; Yellow: medium polluted waters; Green: slightly polluted waters; Blue: clean unpolluted waters.

Indexes	Otesevo	Nakolec	Krani
N(ind/m^2)	1250	3250	1725
Number of species S	5	8	8
Shannon&Weaner H	2.5	2.2	2.57
Margalef d	2.26	3.7	4.02
Pielou e	0.83	0.58	0.38
Simpson c	0.21	0.37	0.31

The ASPT index served as a sensitive and ecologically meaningful metric for assessing biological integrity, particularly in nutrient-enriched systems. According to its scoring thresholds, none of the surveyed localities met the criteria for good ecological status. Notably, the site at Oteshevo was classified as having a bad ecological status, while the remaining localities were characterized by poor ecological status (Table 6). These findings further reinforce the limitations of traditional diversity indices and underscore the diagnostic

value of ASPT in capturing anthropogenic impacts that may be obscured by structural metrics alone.

Table 6. Ecological status of localities according to the ASPT index (autumn 2022)
*Red: bad ecological status; Orange: poor ecological status

Index	Otesevo	Nakolec	Krani
ASPT			

Figure 1. View of an autumn sample from the Nakolec locality at a depth of 5 meters.

DISCUSSION

Macrophytes and macrozoobenthos are important for structure and function of aquatic ecosystems (Varadinova et al. 2023). Aquatic macrophytes increase habitat diversity and provide refuge for invertebrates, thus impacting their species composition and abundance (Pinto et al. 2006). Benthic macroinvertebrates are more sensitive to organic pollution, as they are directly affected by variations in oxygen levels. Anthropogenic stressors, such as altered hydrological regime from hydropower, organic pollution, and nitrogen loads in its inorganic forms, appear to have a considerable effect on river aquatic macrophyte communities (Varadinova et al. 2023).

Macroinvertebrate metrics are useful tools for assessing water quality and the overall health of aquatic ecosystem. Freshwater macroinvertebrate taxa vary in response to organic pollution; thus, their diversity and community composition have been used to make inferences about pollution loads (Tampo et al 2021). Additionally, zoobenthos provide carbon dioxide to promote photosynthesis and improve sediment soil quality, fostering macrophyte growth (Tan et al. 2017).

Table 5 presents the ecological status of the sampling sites as assessed by traditional diversity indices. While the Pielou evenness and Simpson diversity indices suggest a wide range of environmental conditions—from very good to poor—their outputs appear inconsistent with other key indicators of ecological degradation. In contrast, the values of the Shannon–Weaver diversity index (H) and the Margalef richness index (d) provide a more realistic reflection of the actual ecological status across sites. These latter indices better align with the elevated total phosphorus concentrations and the macrophyte-based index (Schneider et al. 2020; Trajanovska et al. 2014,Budzakoska-Gjoreska et al. 2024; Trajanovski et al. 2023), both of which indicate eutrophication and declining ecological integrity in Lake Prespa. This discrepancy underscores the limitations of relying solely on structural evenness metrics in shallow, nutrient-sensitive systems, where compositional and functional indicators offer a more accurate diagnostic of ecological condition.

To address these limitations, the ASPT (Average Score Per Taxon) index has been applied as a more robust and ecologically meaningful metric. Its reliability is supported by previous research on natural lakes in North Macedonia—including Lake Prespa—where

ASPT has consistently demonstrated strong correspondence with nutrient levels, organic pollution, and biological integrity (Schneider et al. 2014, Trajanovska et al. 2019,Budzakoska-Gjoreska et al. 2024a; Trajanovski et al. 2024). As such, ASPT serves as a critical complementary tool for ecological status assessment, particularly in systems where traditional diversity indices may obscure underlying degradation.

CONCLUSION

This study was limited to autumn sampling at three localities, which may not reflect seasonal or spatial variability. Future research should include sampling across different seasons and additional sites to provide a more comprehensive assessment of ecological dynamics and environmental pressures.

Based on the ASPT (Average Score Per Taxon) index, none of the investigated localities in Lake Prespa during the autumn 2022 campaign achieved good ecological status. The site at Oteshevo was classified as having bad ecological status, while all remaining sites were assessed as poor. These results confirm the ASPT index as a sensitive and reliable bioindicator, capable of revealing ecological degradation that may be overlooked by traditional diversity metrics. Its application reinforces the need for functionally grounded indices in assessing nutrient - enriched freshwater systems.

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IRON DEFICIENCY ANEMIA IN PREGNANCY: PREVALENCE, DIAGNOSIS, AND PUBLIC HEALTH STRATEGIES

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ABSTRACT

Introduction: *Iron deficiency anemia (IDA) is the most common nutritional disorder worldwide and the leading cause of anemia during pregnancy. Pregnant women are particularly vulnerable due to increased iron demands, posing risks for both maternal and fetal health. The aim of this study is to assess the prevalence, diagnostic approaches, and public health strategies related to IDA in pregnancy.*
Methods: *A review of epidemiological data from the World Health Organization (WHO), relevant literature, and national health registries was conducted. Diagnostic standards based on hemoglobin concentration and serum ferritin levels were evaluated, along with screening and iron supplementation strategies within antenatal care.*
Results: *According to WHO data, more than 40% of pregnant women globally suffer from anemia, with iron deficiency being the main cause. The highest prevalence is recorded in South Asia and Sub-Saharan Africa, but moderate prevalence is also seen in parts of Europe and the Balkans. Early screening and iron supplementation during pregnancy have shown positive outcomes, including a measurable decrease in maternal anemia and associated complications.*
Discussion: *The findings highlight the need for standardized prenatal screening protocols and universal supplementation policies. Barriers include limited access to health services, lack of awareness, and low adherence to supplementation. Improving maternal health requires strengthened public health initiatives, education on nutrition, and equitable access to prenatal care. Further research is needed to optimize timing and delivery of interventions.*

Keywords: iron deficiency, anemia, pregnancy, maternal health, supplementation

1. INTRODUCTION

Iron deficiency anemia is the most common type of anemia globally and is one of the most widespread nutritional disorders in the world [1]. Iron is a trace element required for the synthesis of hemoglobin, myoglobin, oxygen transport and cellular metabolism [2]. During pregnancy, the body's need for iron increases by about 50-100% compared to normal women, these needs are due to the growth of the fetus in utero, an increase in maternal blood volume and the development of the placenta [3].

Microcytic and hypochromic anemia are the most common forms of anemia in pregnant women and are the result of insufficient intake or absorption of iron, which leads to a gradual depletion of ferritin reserves [4]. The clinical picture of iron deficiency anemia during pregnancy includes tachycardia, fatigue, reduced resistance to infections, an increased risk of premature birth, low birth weight and perinatal mortality [5].

In the Republic of North Macedonia, anemia is a significant health problem among pregnant women. It is diagnosed in every third to fourth pregnancy, and according to the World Health Organization, the country is classified among those with a moderate prevalence of anemia [6]. Since the condition is preventable, public health policy must focus on systematic screening, accessible supplementation, and education of women of reproductive age.

2. PATHOPHYSIOLOGY OF IRON DEFICIENCY ANEMIA

During pregnancy, iron requirements increase by approximately 1000 mg. Of this amount, about 300 mg are used for fetal and placental development, 500 mg for the expansion of maternal erythrocyte mass, and around 200 mg are lost through physiological processes [7]. Iron is absorbed in the duodenum in the Fe^{2+} form, and its absorption is facilitated by vitamin C and an acidic environment [8]. Iron is stored as ferritin in the liver, spleen, and bone marrow. A deficiency leads to impaired erythropoiesis, increased reticulocyte count in peripheral blood, and the appearance of microcytic, hypochromic erythrocytes with reduced hemoglobin.content.

During the second trimester, physiological hemodilution occurs, causing a temporary decrease in hemoglobin levels. However, if hemoglobin concentration falls below 105 g/L, this indicates a pathological process and true anemia [9].

3. LITERATURE REVIEW

According to WHO data, 41.8% of pregnant women worldwide suffer from anemia, and about half of these—approximately 22%—have iron deficiency anemia. Other types include megaloblastic and hemolytic anemias [10].

In low-income countries, prevalence can reach up to 60%, whereas in more developed countries, due to higher socioeconomic status and better nutrition, rates drop significantly to 10–20% [11].

Numerous European studies show that Balkan countries have a moderate prevalence of IDA, with the highest rates observed in Serbia (35%), Bosnia and Herzegovina (32%), and slightly lower rates in North Macedonia (28%) [12].

Literature and research evidence confirm that iron deficiency is primarily related to poor nutrition, low dietary iron intake, insufficient health education, and inappropriate use of iron supplements [13,14]. Additional risk factors include recurrent infections, frequent parasitic infestations in some regions, and short intervals between pregnancies [15].

The WHO recommends prophylactic supplementation with 30–60 mg of elemental iron and 400 µg of folic acid daily for all pregnant women [16]. Regular supplementation significantly reduces the incidence of anemia, improves placental blood flow, and lowers the risk of postpartum hemorrhage [17].

4. METHODS

A systematic analysis of data from multiple sources was performed, including the World Health Organization (WHO Global Database on Anaemia), the Ministry of Health of the Republic of North Macedonia (National Reports 2018–2023), the Institute of Public Health of North Macedonia, and published scientific papers indexed in PubMed, Scopus, and Google Scholar-(2005–2024).
Keywords used: *iron deficiency anemia, pregnancy, North Macedonia, public health strategies*.
A total of 42 sources were reviewed, of which 25 were retained based on relevance and methodological quality.

5. RESULTS

5.1 Global Trends

According to global estimates, iron deficiency accounts for approximately 70% of all anemia cases during pregnancy [18].

5.2 Situation in North Macedonia

According to data from the Institute of Public Health, 27.4% of pregnant women in North Macedonia in 2022 had hemoglobin values below 110 g/L. Therefore, WHO categorizes the country among those with a moderate risk of iron deficiency anemia [19].
Women from rural areas and those with lower education levels are most affected.
Although WHO recommends routine supplementation with iron, vitamin C, and folic acid from the first trimester, studies indicate that about 35% of pregnant women do not take iron supplements regularly. The most commonly cited reasons include gastrointestinal side effects and insufficient awareness or education [20].

6. DISCUSSION

Iron deficiency anemia is a multifactorial condition that requires an integrated approach for effective prevention and management. Iron is an inexpensive and widely available micronutrient, but the deficiency persists due to low health literacy and improper supplement use [21].

In North Macedonia, pregnant women routinely undergo blood count testing each trimester. However, due to limited resources and reagents, serum ferritin measurements—which are the key indicator of iron stores—are often unavailable in smaller healthcare facilities [22].

To reduce the incidence of iron deficiency anemia, the following actions are recommended:

- Strengthening antenatal screening — mandatory anemia testing in the first and third trimesters;
- Educational programs for pregnant women — provided by obstetricians and public health nurses on proper supplement use and nutrition;
- Nutritional support programs — promoting consumption of iron- and vitamin C–rich foods;
- Intersectoral collaboration — coordinated actions between the Ministries of Health, Education, and media campaigns;
- Continuous monitoring — establishing a national registry for anemia in pregnancy and ensuring state-level follow-up and support.

Public health intervention models implemented in Croatia and Slovenia have demonstrated excellent results, reducing prevalence below 15% [24].

7. CONCLUSION

Iron deficiency anemia is a significant health problem in North Macedonia. In order to reduce maternal mortality and prevent poor perinatal outcome of pregnancy, effective primary prevention, timely diagnosis of anemia and taking measures to eliminate it with proper nutrition or the use of appropriate iron preparations are necessary.

In addition to the treatment of pregnant women, the state also needs to take preventive measures such as implementing a national program for the prevention and early detection of iron deficiency anemia; integrating nutrition education for pregnant women within the framework of prenatal care;

Providing financial support and equal access to iron supplements for all women, especially those from rural and Roma communities.

Such a strategy would improve the health of mothers and children and reduce the overall burden of anemia in the country.

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A MULTIDIMENSIONAL FRAMEWORK FOR PSYCHOMOTOR REHABILITATION AND INCLUSIVE EDUCATION IN CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

This research used an interdisciplinary model that integrates psychomotor rehabilitation with inclusive education for students with cerebral palsy. The research revealed the need for individualized, specific rehabilitation that supports functional independence and active participation in learning environments. A case study design was used including a nine-year-old girl with spastic diplegic cerebral palsy attending a regular school. Standardized instruments such as the Gross motor function classification system, Manual ability classification system, Modified Ashworth scale, and Pediatric evaluation of disability inventory were used. Cognitive, communicative, social and emotional functioning were assessed through classroom observations, evaluations, and interviews. The results showed moderate motor limitations and dysarthric speech but preserved visual perception, motivation, and symbolic understanding. Environmental and systemic barriers such as fragmented rehabilitation services and insufficient interprofessional collaboration limited her progress. The results clarify the relevance of coordinated, family-centered intervention integrating rehabilitation, education, and social support to improve inclusion and general development in children with cerebral palsy.

Keywords: cerebral palsy; psychomotor rehabilitation; inclusive education; motor learning; special education; child development; multidisciplinary approach.

INTRODUCTION

Cerebral palsy is one of the most common causes of motor impairment in childhood and it's characterized by chronicmovement abnormalities and posture resulting from static disfunctions in the developing brain (Patel et al., 2020). Children with this condition experience combined functional disabilitiesincluding gross and fine motor control, coordination, balance, and speech, combined with cognitive, perceptual, and socio-emotional problems (Himmelmann et al., 2006; Al-Nemr& Abdelazeim, 2017). These complex problems affect the skills level of the child for independent functioning and participation in daily life and educational activities, making early and continuous rehabilitation important for improving developmental results and social inclusion (Pashmdarfard et al., 2021;Albesher et al., 2025).

Psychomotor rehabilitation stands as a principal component in improving the quality of life and daily functioning of persons with cerebral palsy (Poursadoughi et al., 2015; Dogruoz Karatekin& Icagasioglu, 2022). Within this context, rehabilitation is not limited only to physiotherapy but develops into an integrative approachincluding occupational therapy, special education, communication support, and family involvement in the rehabilitation process (Faccioli et al., 2023). Effective psychomotor rehabilitation consequently relies on collaboration between various professionals such as physiotherapists, special educators, psychologists, and speech therapistworking together aiming at common functional objectives (Sacaze et al., 2013; Dončevová et al., 2016).

At the same time, inclusive education gives the pedagogical and social structure necessary to maintain that children with disabilities participate in learning environments (Budnyk& Sydoriv, 2019). It focuses on equal access, adaptation of curricula, individualized educational plans, and a supportive school culture that values diversity and participation (Ranbir, 2024; Dewi, 2034). For children with cerebral palsy, inclusion is not simply about physical presence in classrooms - it includes removing attitudinal, architectural, and methodological barriers that limit their involvement and learning (Carrillo-Sierra et al., 2025). Inclusive education therefore becomes a fundamental context where the results from rehabilitation lead to everyday practice, social interaction, and academic progress (Kefallinou et al., 2020).

Children with cerebral palsy continue to meet considerable resistance in achieving functional independence and educational inclusion due to inconsistent rehabilitation, insufficient interprofessional coordination, and limited adaptation of school environments (Casseus& Cheng,2021; Rashikj Canevska & Chichevska Jovanova, 2020). This research intends to develop and analyze a multidimensional framework that unites psychomotor rehabilitation with inclusive education, focusing on the integration of medical, psychological, and pedagogical approaches. The main objective is to create a comprehensive model that improves functional capacity, learning participation, and social inclusion of children with cerebral palsy with help of coordinated action among health, educational, and family systems. The importance of this researchis defined by its potential to fill the gap between rehabilitation and education by promoting sustainable inclusion practices, improving interdisciplinary cooperation, and strengthening strategies that support holistic child development.

METHODS

Study design

This research was designed as a case-based descriptive analysis integrating quantitative and qualitative methods to examine the psychomotor, cognitive, and socio-emotional functioning of a child with spastic diplegic cerebral palsy within an inclusive educational environment. The investigation combined psychomotor assessments and contextual educational observations to construct a multidimensional rehabilitation and

inclusion framework. The research was conducted at the Primary Resource School "Kocho Racin" in Bitola.

Participants

The participant was a nine-year-old girl diagnosed with spastic diplegic cerebral palsy and included in a primary school program with individualized educational support. She showed moderate to severe psychomotor impairments including muscle spasticity, postural instability, and dysarthric speech. The family environment was supportive but characterized by limited access to continuous rehabilitation. Inclusion criteria included confirmed diagnosis of cerebral palsy and current admission in an inclusive school program; exclusion criteria included comorbid intellectual disabilities or uncontrolled epilepsy.

Materials and instruments

A series of standardized and adapted instruments were used to assess psychomotor and functional performance:Gross motor function classification system (GMFCS) and Manual ability classification system (MACS) for motor functioning.Modified Ashworth scale (MAS) for spasticity grading.Pediatric evaluation of disability inventory (PEDI) for functional independence.Subiran, Buche, and Reye coordination tests for postural, manual, and fine motor control.Cognitive and gnostic assessments (classification, seriation, correspondence, conservation tasks) taken from Piagetian developmental scales.Behavioral and emotional functioning was evaluated through systematic observation and teacher-parent interviews with focus on adaptability, participation, and motivation in the school context.

Procedure

Data collection took place over a six-week observation and evaluation period during the 2024/2025 academic year.Initial assessment was conducted at the Clinical Hospital "Dr. Trifun Panovski" -Bitola from neurologist where the diagnosis was established. Psychomotor evaluation was performed by a multidisciplinary team including a special educator, physiotherapist, and speech therapistfollowing standardized protocols for upper and lower limb coordination, fine motor differentiation, and praxis organization.Educational observation was implemented within classroom sessions, individualized instruction, and free-play contexts to document participation and social integration.Environmental and family assessments evaluated accessibility, parental involvement, and emotional climate.Intervention recommendations were designed based on the observed strengths and limitations, pointing out individualized psychomotor stimulation, structured routines, and collaborative work between rehabilitation and educational teams.

Data analysis

Descriptive and interpretative analyses were performed. Quantitative data from psychomotor and functional scales were presented into frequency and performance tables, while qualitative data (teacher and parent reports, observational notes) were thematically analyzed to identify patterns of adaptive behavior, barriers, and facilitators of inclusion. Results were integrated into the proposed Multidimensional framework for psychomotor rehabilitation and inclusive education, connecting motor, cognitive, and emotional development dimensions into a cohesive intervention model.

RESULTS

The results presents the child's psychomotor, cognitive, communicative, and social-emotional development based on standardized assessments, observational data, and functional evaluations. The results are organized thematically to show the multidimensional approach of this research, integrating motor function, perceptual and cognitive abilities, communication skills, and adaptive behavior within the educational and family context.

Table 1: General functional classification of the child with spastic diplegic cerebral palsy.

Category	Assessment tool	Result orlevel	Functional description
Gross motor function	GMFCS (Gross motor function classification system)	Level II	Walks with limitations, independent mobility in short distances, difficulties with balance and running.
Manual ability	MACS (Manual ability classification system)	Level II-III	Handles most objects with reduced speed and precision, needs minimal assistance for complex manipulations.
Muscle tone	Modified Ashworth scale	Grade 2 (moderate spasticity)	Increased tone in lower limbs, especially hip flexors and adductors; mild asymmetry of upper limbs.
Functional independence	Pediatric disability inventory	Moderate dependence	Requires partial assistance in dressing, hygiene, and classroom tasks.
Communication function	Observational and speech assessment	Partially functional	Expressive speech limited by dysarthria; comprehension preserved for simple instructions.

Table 1 shows the starting point of functional profile of the child according to internationally recognized classification systems. The results indicate moderate spasticity, partial independence in daily activities, and maintained cognitive comprehension despite expressive speech limitations.

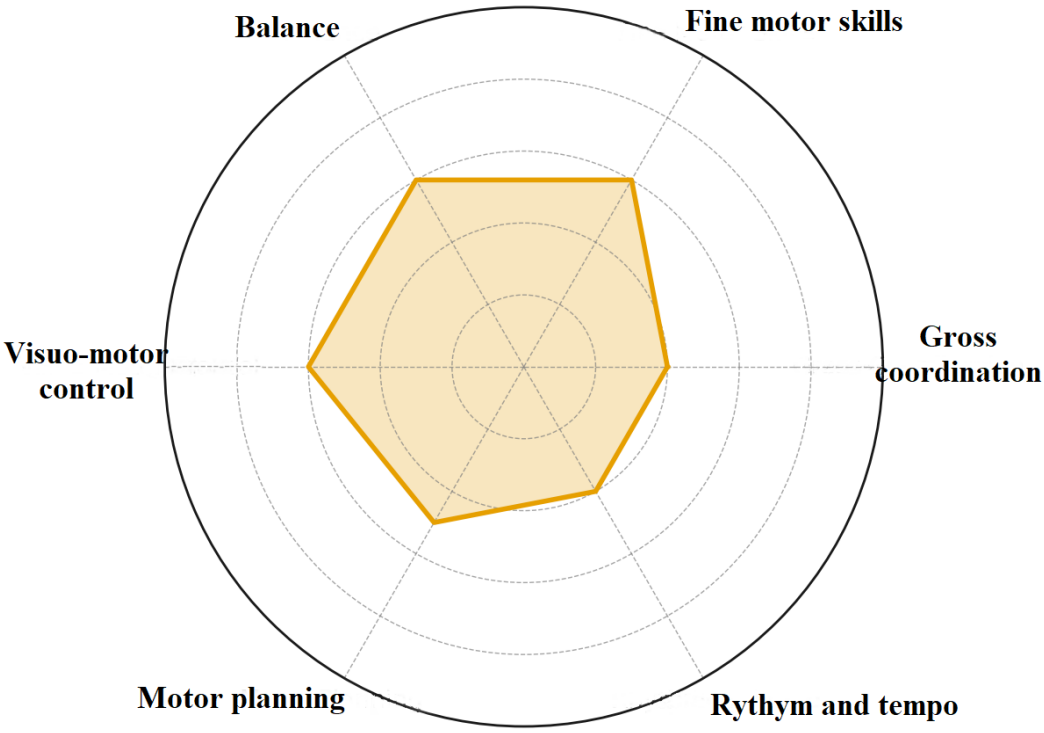

Figure 1: Psychomotor function radar profile of the child.

Figure 1 shows the psychomotor performance across six categories: balance, fine motor skills, gross coordination, visuo-motor control, motor planning, and rhythm and tempo. The results show moderate functional limitations in coordination, rhythm, and balance. Some strengths are visual-motor integration and fine motor adaptation, which remain relatively preserved when guided by visual models. This figure also shows the interdependence of motor, perceptual, and planning abilities, defining the need for a multidimensional therapeutic approach integrating physical, cognitive, and educational interventions.

Table 2: Speech, communication, and cognitive profile of the child.

Category	Summary of the performance	Observation
Speech and language	Dysarthric, limited fluency	Articulation slow and imprecise; expressive output brief but contextually appropriate.
Comprehension	Preserved for simple commands	Understands concrete instructions; needs repetition for complex verbal input.
Cognition	Low-average range	Visual reasoning stronger than verbal; benefits from structured and visual tasks.
Attention and memory	Inconsistent	Short attention span; visual memory more reliable than auditory.

Table 2 shows that the child's communication is partially functional, with evident motor-speech and articulation difficulties due to dysarthria. While expressive speech remains limited, comprehension of familiar verbal instructions is relatively intact, allowing successful participation in guided tasks. Cognitive assessment indicates heterogeneous abilities, with strengths in visual perception and task imitation, compensating for weaker auditory processing and attention control.

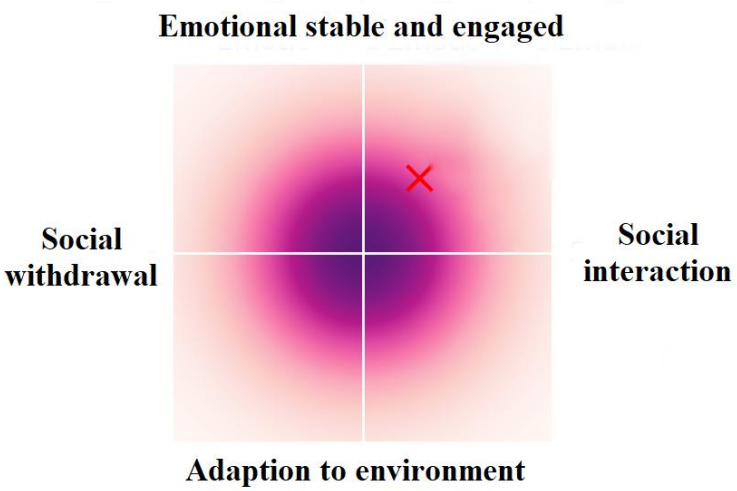

Figure 2: Emotional landscape diagram for social engagement and emotional stability.

Figure 2 uses a two-dimensional heatmap to show how the child balances inner emotional stability with social engagement and environmental adaptation. The vertical axis extends over from high emotional stability and engagement at the top to adaptation to environment at the bottom, while the horizontal axis ranges from social withdrawal on the left to social interaction on the right. The shaded centre show areas of moderate adaptation and emotional activity, with lighter regions showing greater stability and engagement. The red marker placed in the upper right quadrant shows that the child is mostly emotionally stable and socially engaged, suggesting strong resilience and active participation in social contexts. At the same time, the gradient around the centre show that environmental adaptation and coping

skills are less developed, coordinating support to strengthen adaptability while maintaining the child's positive emotional and social profile.

Table 3: Summary of therapeutic and educational interventions applied to the child.

Category	Applied methods	Summary of the effects
Physiotherapy	Bobath and Vojta techniques, balance and stretching exercises	Improved trunk control and gait stability
Occupational therapy	Fine motor and activities of daily living training	Greater independence in self-care and classroom tasks
Speech therapy	Articulation drills, breathing control, augmentative and alternative communication support	Better expressive clarity and vocabulary use
Cognitive stimulation	Visual sequencing and memory tasks	Increased attention and task persistence
Emotional–Social Training	Role-play and peer interaction games	Enhanced emotional regulation and group adaptation
Educational inclusion	Individualized education plan	Continuous academic participation and social integration

Table 3 shows a multidimensional and coordinated rehabilitation plan that shows both clinical and educational aspects. Combined therapeutic efforts have led to improvements in motor coordination, communication, emotional stability, and functional independence, while inclusion in the schoolmaintain sustained progress and active participation in daily activities.

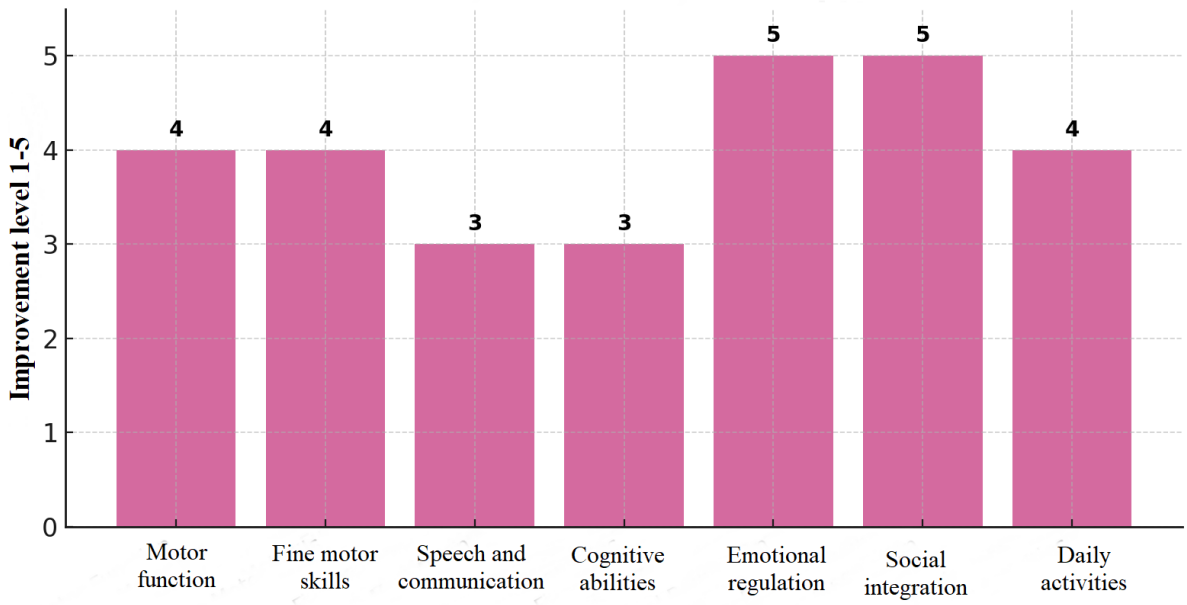

Figure 3: Evaluation of the progress of the child.

Figure 3 shows the path of the developmental growth achieved through a structured, interdisciplinary rehabilitation plan. This shows clear differentiation across seven categories such as motor function, fine motor skills, speech and communication, cognitive abilities, emotional regulation, social integration, and daily living activitieseach showing specific dimension of psychomotor and adaptive growth of the child.The most pronounced gains are observed in emotional regulation and social integration, indicating the child's improved ability to maintain emotional balance and participate in peer and social interactions. These improvements are important given the initial difficulties with communication and adaptive functioning, showing that emotional stability and social motivation have become supporting factors for therapeutic progress.Moderate but consistent improvement is evident in motor and fine motor categories, confirming the positive results of sustained physiotherapeutic and

occupational interventions focusing on balance, coordination, and self-care activities. Speech and communication show steady but slower advancement and this is an expected trend in children with spastic diplegic cerebral palsy due to persisting articulatory and respiratory control limitations. Cognitive development also shows gradual improvement, primarily in structured reasoning and visual memory, showing effective use of visual-motor integration strategies.Finally, the category of daily activities confirms growing independence in functional routines such as dressing, feeding, and school participation. The pattern across categoriesshows that emotional and social stability act as facilitators for functional independence, improving the adaptability of the child within both therapeutic and educational environments.

DISCUSSION

The results of this researchshow the interaction between psychomotor limitations and educational participation in children with spastic diplegic cerebral palsy. The results confirm that motor impairments such as reduced balance, coordination, and manual dexterity are the main barrier to functional independence and active participation in the classroom. Despite these challenges, the child showed adaptive capacities - strong visual perception, symbolic comprehension, and consistent motivation when supported through individualized and visually structured activities.

From a rehabilitation perspective, the integration of neurodevelopmental approaches and task-specific exercises improved both trunk stability and functional movement patterns, creating a foundation for improved learning performance. On the educational side, inclusive teaching practices, visual aids, and environmental adjustments were found to increase participation and self-confidence within the classroom. The interaction between therapeutic and pedagogical strategies shows the necessity of a coordinated multidisciplinary model, where healthcare workers, educators, and families design interventions with aim tomaximize functional independence and academic achievement.

One research by Setaro et al., (2025)strengthens the literature byfocusing on the importance of multidimensional and integrative rehabilitation such as the AMIRA model in promoting development among children with cerebral palsy. Similar to AMIRA's focus on early, adaptive, and environment-based intervention, our results confirm that individualized rehabilitation programscombining psychomotor therapy, cognitive stimulation, and inclusive educationlead to improvements across motor, emotional, and social categories. The integration of physical rehabilitation with educational and emotional support proved to be the most influential factor in improving functional independence and participation in daily and classroom activities.

Comparable to the principles of the A.MO.GIOCO model, which focuses on task-oriented motor learning through play and parent involvement, the results of Foscan et al., (2024)show the value of play-based and functionally meaningful activities in improving psychomotor results in children with cerebral palsy. The A.MO.GIOCO approach, developed as a structured yet flexible framework focused on child motivation and active participation, aligns closely with our research. Both approaches prioritize contextual learning, sensory-motor integration, and emotional engagement as important components of neuroplastic change and functional improvement.

The study by Klaić et al. further shows the concept that multidimensional assessment is important for effective educational and rehabilitation planning for students with cerebral palsy. Their contextual evaluationconducted both in clinical and school environmentsconfirms that understanding the abilities of the child requires an integrative perspective including motor, cognitive, emotional, and environmental factors. Similarly, our resultsshow that comprehensive assessment and individualized intervention are inseparable

processes; only by analyzing both internal and contextual conditions can teachers and therapists design interventions that truly promote learning participation and inclusion.

The Porridge-Like Framework proposed by Provenzi et al. (2021) adds an important family-centered dimension to the understanding of multidimensional rehabilitation and education in children with developmental disabilities. By conceptualizing the parent-child dynamic through the ABCD model including affective, behavioral, cognitive, and disability-related components, the authors show that effective child rehabilitation must also include emotional and psychological support for families. This connects with our results where parental involvement and emotional stability were found as important determinants of the adaptive progress and motivation of the child.

Limitations and future directions

This research is based on a single case analysis, which limits the generalizability of the results. Although the multidimensional framework provided informationabout the interaction between psychomotor rehabilitation and inclusive education, its applicability to broader populations of children with cerebral palsy requires further validation. The assessment tools and observations were context-specific, and the absence of long-term follow-up data restricts the evaluation of sustained outcomes.

Future research should focus on larger longitudinal researches that combine quantitative and qualitative methodologies to explore the effects of integrated special education and rehabilitation programs. Comparative research across various educational environments would help identify the contextual factors that enhance inclusion and functional independence. Future researches should examine family-centered and digital-supported rehabilitation with aim to optimize accessibility and continuity of care within both clinical and school environments.

CONCLUSION

This researchshowed that a multidimensional framework integrating psychomotor rehabilitation, cognitive stimulation, emotional regulation, and inclusive education can improve functional independence and participation in children with cerebral palsy. The resultsshow that coordinated collaboration among rehabilitation workers, teachers and families creates the most favorable conditions for developmental progress. The structured assessment of motor, emotional, and learning abilities allowed for individualized goal and measurable improvements across all domains.

The results view rehabilitation and education not as separate entities, but as interdependent components of an integrated developmental system. Future rehabilitation programs should continue to integrate physical, emotional, and educational interventions in natural environments, making sure that therapeutic gains translate into daily functioning and school success. The multidimensional framework presented here serves as both a clinical and educational model for promoting inclusion, autonomy, and lifelong learning in children with cerebral palsy.

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DIGITAL TECHNOLOGIES IN PUBLIC ADMINISTRATION: A CASE STUDY OF ESTONIA'S E-GOVERNANCE FOR INCLUSIVE AND SUSTAINABLE DEVELOPMENT

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ABSTRACT

Introduction: *In today's world, increasingly afflicted by inequality, climate change, and governance problems, the United Nations Sustainable Development Goals (UN SDGs) underscore the necessity of fostering inclusive and sustainable societies. Digital technologies provide a critical avenue for realizing these objectives and Estonia, a small Baltic nation, stands as an exemplary global example of this potential.*
Methods: *This qualitative case study uses a narrative approach to explore how the Estonian national government utilized digital technology to digitize public administration, including in the domains of education, taxation, and justice, with the aim of fostering inclusive and sustainable societies, drawing on peer-reviewed studies, government records, and industry reports. The study also underscores the nation's steadfast commitment to safeguarding privacy and cybersecurity, while also highlighting, scaling and sustainability challenges currently experienced by the nation.*
Results and Discussion: *The findings of the study indicate that Estonia's e-governance, facilitated by digital technologies and characterized by features such as e-voting, e-education, e-health, e-ID, e-residency, e-business tools, e-justice, and data embassy has enhanced public engagement, decreased operational expenses, and mitigated environmental effects. These results highlight how a government driven by digital technology is guiding the nation towards greater inclusivity and sustainability. Additionally, it emphasizes that inter-sectoral collaboration and strategic approaches to improve cyber resilience is crucial to the success of e-governance and ultimately to the establishment of inclusive and sustainable societies. The study concludes that Estonia's e-governance has helped establish inclusive and sustainable societies and furthered equitable and sustainable development in accordance with the United Nations Sustainable Development Goals, including SDG 9 (Industry, Innovation and Infrastructure), SDG 10 (Reduced Inequalities), and SDG 16 (Peace, Justice and Strong Institutions). It underscores equitable practices, strong inter-sectoral collaboration and strategic and proactive governance are crucial for enabling technology-driven public administration.*
Originality and Value: *Building inclusive and sustainable societies is increasingly significant, in today's world where governments are seeking governance frameworks that are transparent, effective, and people-oriented. This study offers policy makers and strategists of*

other nations much-needed guidance on how digital technologies can be leveraged to improve public administration for building inclusive and sustainable societies.

Keywords: digital governance, inclusive development, public administration, sustainable development, strategic governance

INTRODUCTION

Estonia, a small Baltic nation with 1.3 million people, has established itself as a global frontrunner in utilizing innovation and technology to attain inclusive and sustainable development via e-governance. After gaining independence from the Soviet Union, Estonia lacked an administrative foundation and chose to establish a digital state from the ground up, prioritizing innovation and technology in its public sector administration to foster inclusive and sustainable growth. National e-governance system had the widespread use of e-public services like taxation, health, education, voting, and judicial process by the masses, thereby resulting in widespread cost reduction, empowering the masses, improving transparency, and removing bureaucratic inefficiency, thereby resulting in inclusive and sustainable growth (International Monetary Fund, 2018), (Espinosa & Pino, 2024)&(Duboise, 2023). Estonia's reform was founded on a clear vision and strong leadership, which brought innovation- and technology-based governance into reality. Its e-government model has become a reference point for nations seeking equitable and sustainable development through strategic technological action. Recognizing that technology-enabled public services are indispensable for national sovereignty and stability over the long term, Estonia opted for in-depth structural transformations rather than short-term digital quick fixes. In the past two decades, this strategic approach has led to the establishment of a fully digital society, in which the majority of public services, including voting, healthcare, and residency, are accessible online. Additionally, nearly all citizens interact with the government through a secure and encrypted digital identity system (Middlemiss, 2023)&(e-Estonia, n.d).

Figure 1 shows the timeline of a few e-public delivery services in the country. It reflects the nation's progress in applying innovation and technology to improve public administration and promote inclusive and sustainable development.

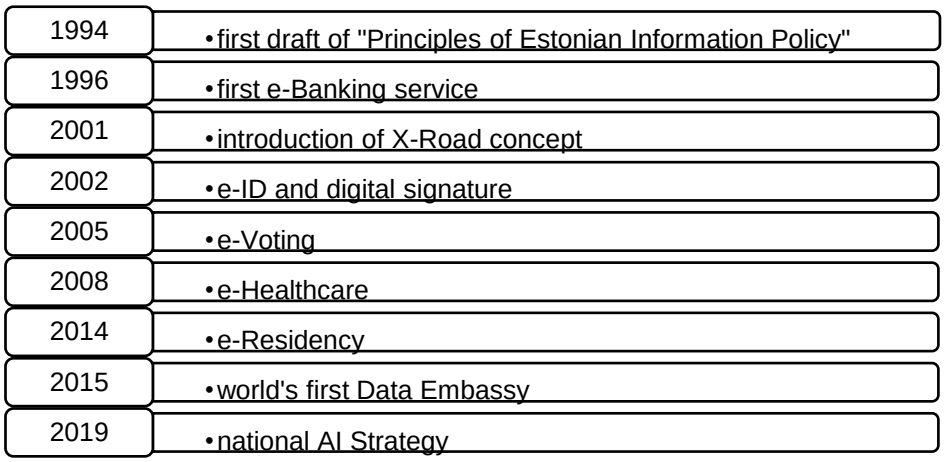


Figure 1. Estonia e-government Timeline (Mechitov & Moshkovich, 2021)

Estonia's digital e-governance based on digital infrastructure is built on X-Road, an open-source data exchange platform that facilitates secure and seamless information exchange between public and private databases. It constitutes the foundation of the nation's e-governance framework, enabling efficient communication across diverse institutions while safeguarding data security and trust. Figure 2 and 3 show the interoperability of the system's components-digital applications, the X-Road data interchange layer, and digital identification-which ensures reliable, secure, and inclusive digital public services (Hardy, 2024)&(Espinosa & Pino, 2024). The nation's key public services such as e-health, e-tax, e-prescription, e-school, and internet voting operate on this shared infrastructure (Adeodato & Pournouri, 2020).

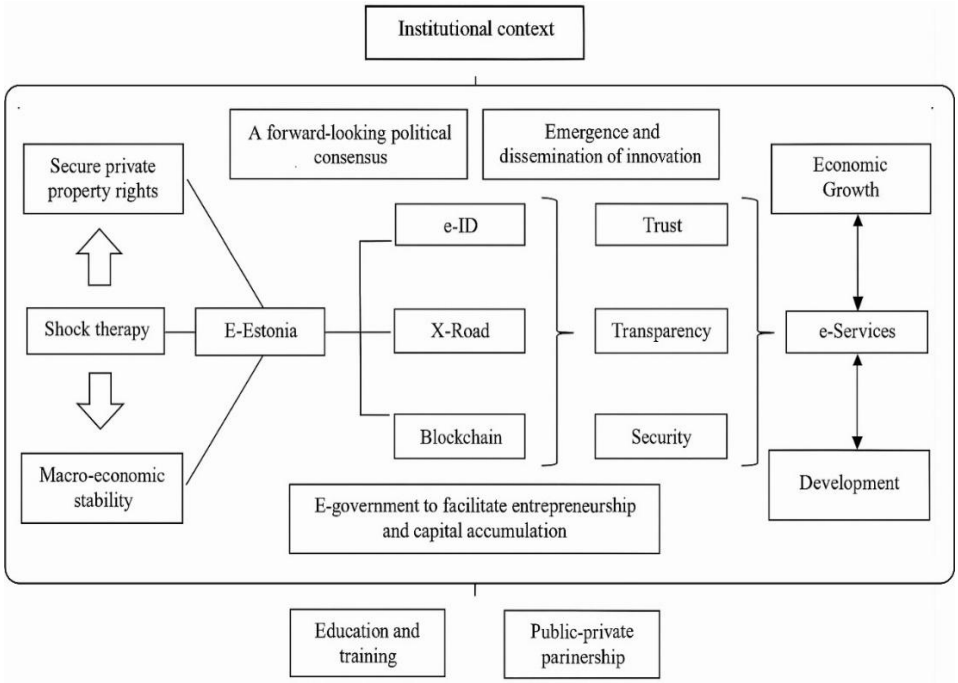
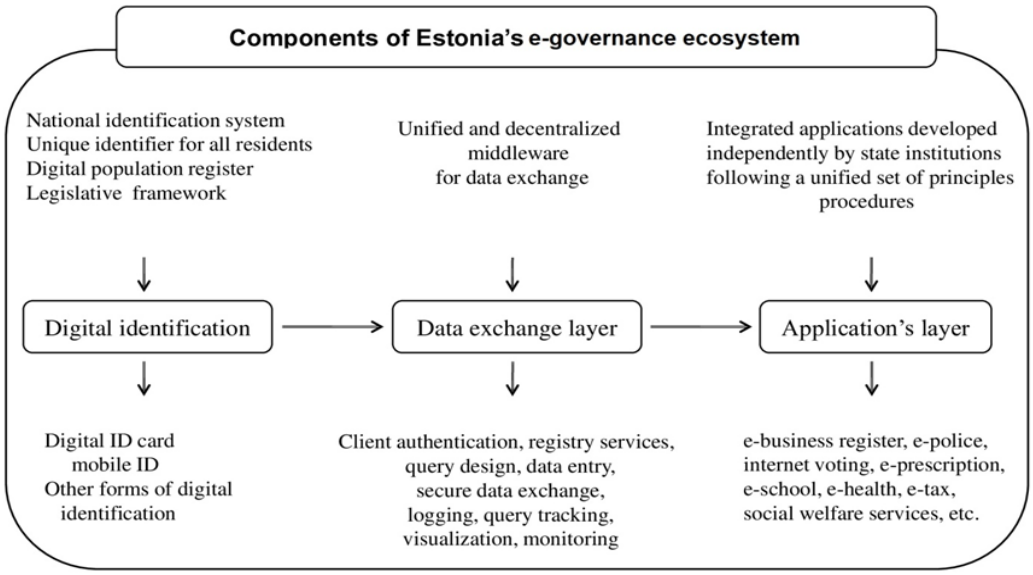


Figure 2. Institutional Foundations and Digital Infrastructure of E-Estonia as a Driver of Development (Espinosa & Pino, 2024)

Figure 3. Components of Estonia's e-Governance Ecosystem
(Adeodato & Pournouri, 2020)



Estonia has transformed traditional public service processes into a seamless, interoperable system by connecting secure digital platforms with a decentralized and integrated data exchange infrastructure. This change not only digitalized services but also made them extremely efficient, paperless, transparent, and accessible to all so that no citizen feels left behind in the digital age. These technological integrations into the e-governance framework have ensured that public services are delivered in a manner that is accountable, accessible, inclusive, and resilient. This has facilitated social inclusion and equity, and it has established the foundation for a digital society that is both inclusive and sustainable.

Review of Literature and Methodology

Estonia's digital governance model is frequently cited in policy and academic discourse as a groundbreaking example of technology and innovation facilitating sustainable and inclusive societies. However, the majority of studies on the subject concentrated on specific aspects of e-governance, addressing single services. For example studies on Estonia frequently highlights single domains, such as e-education (Poldoja, 2020)&(Aru-Chabilan, 2020), e-health (Soares, Ferreira, & Veiga, 2023)& (Metsallik, Ross, Draheim, & Piho, 2018), e-residency (Tammpuu & Masso, 2018)&(Kimmo, Pappel, & Draheim, 2018), e-voting (Clarke & Martens, 2016)&(Agtsahkna, 2013), and smart mobility and transport (Kirejev, Gerstlberger, & Niine, 2024)&(Soe, 2020), highlighting the transformative role of digital solutions in their respective sectors. Few studies have examined its role in providing e-governance consultancies to foreign nations (OECD, 2021), (Remy & Barde, 2024)&(D4D HUB, 2025). Others have emphasized its function in reducing bureaucratic red tape, enhancing transparency, and improving public service delivery (Lember, Kattel, & Tõnurist, 2018), (Stephany, 2020)&(Espinosa & Pino, 2024).

Although these studies provide valuable insights, few present a cohesive perspective of Estonia's e-governance approach as an integrated system. This case study is one among those that aims to provide a comprehensive and holistic overview of core digital services and systems that make up Estonia's e-governance and illustrating how an integrated system of e-governance functions in practice within a national framework. Looking into Estonia's experience as a pioneering example of how technology and innovation can transform public administration to build inclusive and sustainable societies is increasingly significant, in today's world where governments are seeking governance frameworks that are transparent, effective, and people-oriented. This study endeavors to answer the following question: Howhas Estonia leveraged innovation and technology in developing a digitally empowered state that supports inclusive and sustainable national development. In an effort to examine this question, the case study employs narrative approach drawing insights frompeer-reviewed studies, government reports and industry publications to examine Estonia's technology- and innovation-driven initiatives, particularly its core digital services and systems, that have enabled the government to achieve transparent, efficient, and citizen-centric digital governance. The following section of the study explores major government-led initiatives within Estonia's e-governance system. Its digital transformation is being presented not only as a technological accomplishment, but also as a model of how technology and innovation that are aligned with development objectives can modernize governance and inspire global replication. The study also emphasizes that Estonia's digital strategy is profoundly rooted in cyber security and data protection.

Estonia's Digital Model for Inclusive and Sustainable Development

e-Voting: Safe, Accessible, and Sustainable

In 2005, Estonia implemented an e-voting system, becoming the inaugural nation to permit residents to vote online in national elections. The system was developed to improve voter turnout, accessibility, and efficiency in the electoral process, particularly among residents living abroad or in remote areas. Its goal was to make democratic participation more accessible, secure, and transparent (Election Universe, 2019). Voters can authenticate using a government-issued e-ID or Mobile-ID, and the technology protects anonymity by segregating identities from ballots prior to counting. Votes are encrypted, digitally signed, and sent via a secure network. To ensure security, a dedicated application needs to be downloaded just prior to each election. Voters can amend their votes numerous times during the voting period; only the final input is considered, providing protection against coercion (Eremia, Shivananjappa, & Creutzburg, 2025). Between 2005 and 2019, there has been a consistent increase in the number of e-voters (See Fig. 4) (Ehin, Solvak, Willemson, & Vinkel, 2022).

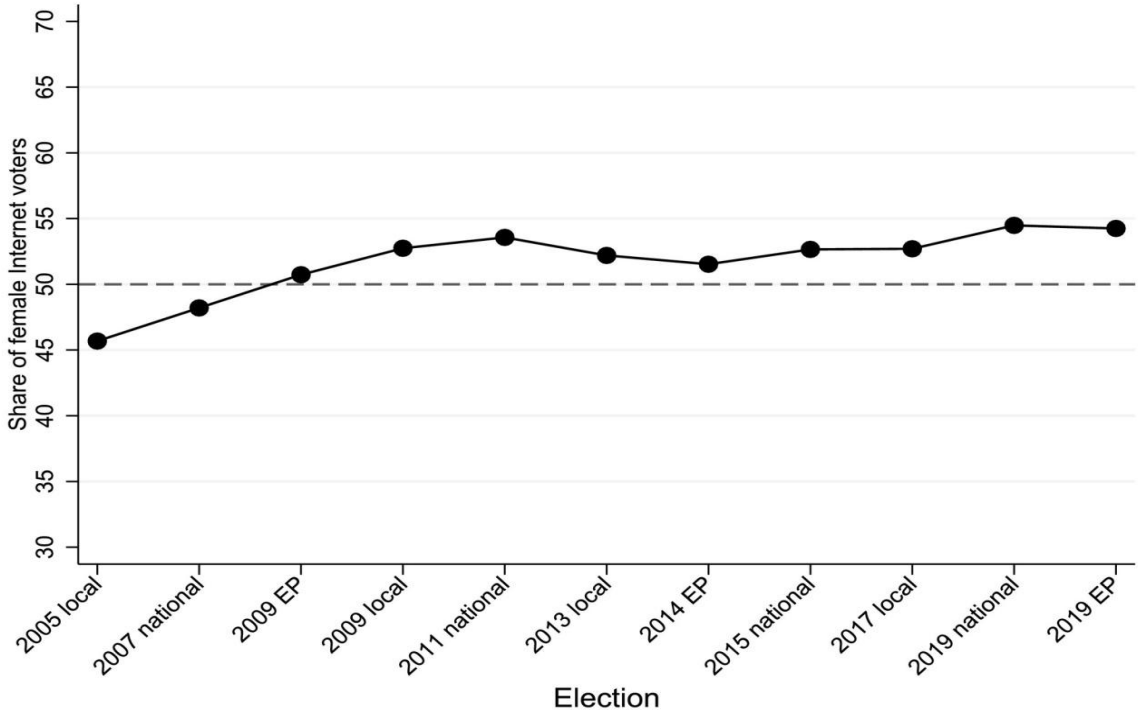


Figure 4. Trends in Internet Voting in National, Local, and European Elections (2005-2019) (Ehin, Solvak, Willemson, & Vinkel, 2022)

Its success lies in its robust digital base, robust auditability and data security focus, and blockchain validation. It replaced paper ballots, reduced administrative expenses, enhanced the accessibility of voters, and is an affordable, green, and transparent system. The Estonian electronic voting system is a shining example of how technology can facilitate democratic and effective governance, improve citizens' participation, and minimize the country's environmental footprint, thus attaining sustainable and inclusive development.

E-Health for All: Inclusive Digital Care

Estonia's Electronic Health Record System (EHR) is a strong example of how digital healthcare can be managed in a sustainable and inclusive way. It is founded on the robust X-Road infrastructure and was launched in 2008, subsequent to the construction of legal foundations in 2000 (The World Bank, 2022). It connects healthcare providers, government systems, and residents to a single, secure, real-time platform, with separate access points for each via a digital identity system. Individuals can review their medical history, medications, treatment bills, and healthcare provider or agency that accessed their information. Personal data control features enable patients to lock or unlock access, hence improving privacy and transparency. Patients can get prompt diagnoses, renew prescriptions, and emergency care from anywhere, eliminating travel, delays, ensuring better health outcomes (Metsallik, Ross, Draheim, & Piho, 2018). It guarantees equal access to healthcare services for urban and rural populations closing the digital divide to a significantly greater degree. For doctors, it gives immediate access to a patient's medical information like lab results, imaging, and case summaries. This allows for faster diagnosis, better provider coordination, and improved continuity of care. Other capabilities, such as prescription, referral, and sick leave certificates, help to streamline administrative duties and reduce the need for in-person visits. Government agencies use the system to track real-time epidemics, plan resources, and issue

digital health, birth, and death certificates (Steinmiller & Ross, 2024)&(e-Estonia, 2016), (e-estonia, 2020). In addition, genomic data is added to the EHR which helps support Estonia's transition to predictive and personalized medicine. Additionally, emergency responders can retrieve important information such as allergies and blood group immediately, which could help provide swift treatment. This digital ecosystem reduces bureaucracy, cut costs, eliminates paper waste, and improves service delivery at all levels. It streamlines operations, increases efficiency, and fosters accountability among patients, providers, and policymakers (Roppel, 2019)& (Election Universe, 2019). Estonia's e-Health approach through EHR exhibits a secure, inclusive, and sustainable digital health system. By bridging the urban-rural divide and improving public trust, it advances the broader goals of building an egalitarian and resilient model of e-governance for inclusive and sustainable development. Since its inception in 2008, Estonia's EHR system has expanded significantly, encompassing around 1.54 million individuals, managing nearly all prescriptions electronically, and facilitating over a million monthly enquiries from patients and healthcare providers (Metsallik, Ross, Draheim, & Piho, 2018).

Estonia's E-Education System: Sustainable E-Schools, Equal Access

Estonia has established itself as a global frontrunner in e-education, founded on the ideals of school autonomy, egalitarianism, and digital-first pedagogy. These pillars have enabled Estonia to attain quality, inclusivity, and future-oriented education via digitalization. Estonian digital education aims to enhance learning by fostering interactivity, creativity, and a student-centered approach, rather than relying solely on screen-based methods (Veldin, Mlekuž, Mägi, & Haugas, 2018). The roots of Estonia's digital education revolution date back to the 1990s when the Tiger Leap program was initiated in 1997. The ambitious initiative for putting technology in education involved ensuring that all the students, irrespective of their socioeconomic background, get access to high-quality education and learning. The program sponsored the installation of computers, internet connections, and digital skills training for educators in schools. By 2001, all Estonian schools had been equipped with internet facilities, marking a swift and successful step into the digital era (Aru-Chabilan, 2020). Additionally, the government improved internet infrastructure, offered digital equipment, and introduced digital literacy courses from an early age through ELLIS, a kindergarten portal, which enabled kindergarten parents to track the progress and activities of their child. In education, the installation of e-Kool, a school management platform, enabled communication between parents, students, and teachers-hence, transparency and participation. These technology tools support Estonia's comprehensive and lifelong digital education plan.

By 2015, Estonia had digitized its educational resources and launched extensive training courses to improve teachers' digital skills. Additionally, through Public-private partnerships a sustainable digital environment was developed Digital platforms such as Stuudium, Opiq, and Moodle were established to improve learning and instruction through interactive content, whilst ETIS and SAIS supported research, student admissions, and academic information management (Põldoja & Laanpere, 2020). Other Digital platforms like the Examination Information System (EIS) facilitate secure online examination with customizable tests that offer instant feedback of student performance. The integration of e-Schoolbag allowed students across all educational levels to easily access vital learning resources from various platforms, hence enhancing the learning process and reducing reliance on physical materials. Despite the prevalence of digital and cloud-based materials in educational settings, traditional literature and classroom activities remain esteemed, preserving balance. Initiatives such as ProgeTiger brought coding and robotics into early

childhood education, while Estonia's wider educational advancements extended to the integration of virtual reality, artificial intelligence, and customized digital textbooks within the curriculum. It proved beneficial when the COVID-19 pandemic struck, Estonia transitioned easily into virtual classes. The educational process proceeded as usual, with more than 90% of institutions employing digital diaries and e-solutions (Burkadze, 2022). In instances of device scarcity, educational institutions, local governments, and civil society organizations addressed the deficiency. For sharing its success with the world, Estonia established the Education Nation program, providing digital solutions, training, consulting, and study tours to help other countries develop digitally resilient education systems (PR Newswire, 2020). Through strategic investment, innovative approaches, and a steadfast commitment to students and teacher empowerment, Estonia has created a resilient digital education system that guarantees equitable access to learning, enhances educational outcomes, and promotes an inclusive and sustainable society.

Smart Mobility and Urban Innovation

Estonia's achievements in smart transport and urban innovation demonstrate the potential for innovation and digital technologies to transform governance systems. In 2011, Estonia implemented an Automated Border Queue Management System for freight carriers to improve the automation of freight management. This enabled driver to reserve slots and go into virtual queues, lowering average border crossing times from 60 hours to only 1.5 hours. This automation greatly enhanced export logistics, minimized traffic jams, and cut air and noise pollution-halves that ultimately spread to domestic ports and logistics centers (Sassiad, 2010). Following the trend, autonomous delivery robots created by Estonian startup, Starship Technologies, started service in Tallinn in 2017, revolutionizing last-mile logistics. These battery-powered, low-speed robots quickly became common in city streets, providing a cleaner and more efficient way to move goods such as food and other goods. In 2019, Estonia reaffirmed its commitment to urban innovation by opening the Twins Smart City Centre of Excellence (CoE) at Tallinn University of Technology, a €32 million initiative co-funded by the EU Horizon 2020 programme and the Estonian government. The CoE was assigned the responsibility of directing the nationwide smart urban renewal initiative through ten pilot projects from 2021-2027. These projects were designed to address regional-specific issues, including climate adaptation and digital mobility (Soe, 2017).

In 2021, the smart transport plans of Estonia received a boost when the first permission for an unmanned self-driving shuttle was granted to a local company, AuveTech. The first autonomous hydrogen car in the world, also manufactured in Estonia, was introduced subsequently. These innovations showcased Estonia's leadership in inter-linked and sustainable transport. Concurrently, Ridango, a public transportation technology company ceased paper tickets and made travelling very convenient by simultaneously introducing account-based ticketing and contactless payment. GPS-based arrival warnings and route guidance were also integrated into real-time public transport tracking apps such as Peatus which means that commuters are able to make more informed decisions, as well as to spend less time waiting. In order to enhance traffic flow, smart traffic lights were implemented at 45 junctions in Tallinn and programmed to prioritize public transport vehicles. These solutions reduced delays while improving overall fleet performance (e-Estonia, 2022). Estonia has also started creating Mobility as a Service (MaaS) services, aiming to consolidate various modes of transport into one digital platform (Kalda, Sell, & Kivimäe, 2024). In low-density rural areas, demand-responsive transport solutions were introduced to save on operation expenses and enhance accessibility.

In Tartu county, Estonia's urbanization featured smart pedestrian crossings, which enhanced pedestrian safety during low-visibility situations. To alert drivers in real time, the crossings were fitted with artificial intelligence motion sensors, LED indicators, and thermal sensors (Pashkevich, Krasilnikova, & Antov, 2016). Accompanying this are smart bus stops in Tallinn, which come equipped with solar panels, USB charging points, Wi-Fi, and real-time arrival displays, adding to sustainability and passenger experience. Accompanying this are smart bus stops in Tallinn, which come equipped with solar panels, USB charging points, Wi-Fi, and real-time arrival displays, adding to sustainability and passenger experience. Bikeep's smartphone-enabled bike racks and e-scooter docks were installed to make secure, app-lockered micro-mobility available, while Comodule's IoT-based solutions provided real-time management of e-bike and e-scooter fleets for operators. Heated sidewalks with sensors were piloted to prevent ice-related accidents and cut chemical use, while an online weather system using mobile and road sensors forecasted road conditions 48 hours in advance to support autonomous winter road maintenance (e-Estonia, n.d)&(Laast, 2024). By deploying solutions from AuveTech, Ridango, Bikeep, Comodule, and Starship Technologies, Estonia has improved urban everyday life, demonstrating the potential of technology-driven mobility to improve public services while building an inclusive, environmentally resilient society.

e-Tax: Tech-Driven Tax for Inclusive Growth

Introduced in 2000 by Tax and Customs Board, the e-Tax system, transformed tax declaration with pre-filled forms, secure access, and rapid processing. It allowed Individuals and enterprises to file income tax, social tax, unemployment insurance, and pension fund contributions. Provision to file Individual income tax returns, customs declarations, and VAT and duty submissions were also offered (Kastik, 2019). The service is defined by speed and ease, with declarations processed in under three minutes and refunds issued within two weeks, encouraging mass adoption and ensuring a seamless experience. Due to these characteristics, e-Tax adoption increased from approximately 59% in 2004 to over 98% by 2019, with more than 98% of all tax declarations now submitted online (Williams, 2021). This tech-driven approach significantly reduced bureaucracy, eliminated the necessity for physical visits, and facilitated global accessibility. It enhanced Estonia's standing as a pioneer in leveraging innovation and technology to foster inclusive public services and supporting an efficient, sustainable, and citizen-centric governance style.

Banking Innovation: Borderless, Paperless, and People-Centric

Estonia was the first to implement e-Banking in the late 1990s. Currently, over 99% of financial transactions are conducted online through secure, user-friendly platforms that are accessible around the clock (e-estonia, n.d). Tuum and Wise, two prominent Estonian fintech businesses, were pioneers in the development of innovative financial products. Tuum's cloud-native, modular core banking system enables banking institutions to efficiently implement and manage a diverse array of digital banking products. Its flexible design enables quick product innovation, easy scaling, and fintech integration, helping banks upgrade legacy systems. Wise's mobile app allows customers to make fast and affordable international money transfers using live currency exchange rates, supported by a global network of local accounts. Customers are able to open accounts, handle finances, and make real-time transactions around the world without setting foot inside a branch (Martens, 2010). The secure e-banking infrastructure is augmented by the integration of e-ID and e-Residency cards, alongside digital authentication and facial recognition capabilities. The system addressed fundamental inefficiencies such as sluggish services and restricted banking hours.

Secure digital identities significantly reduced financial fraud, and connected services were advantageous to businesses and private customers alike. By digitizing banking with e-ID integration, 24/7 online access, and mobile-first solutions, Estonia has enhanced financial services for rural communities, international citizens, and small enterprises, resulting in a more inclusive, accessible, and sustainable financial ecosystem.

e-Business Tools: Innovative, Transparent, and Efficient

Estonia's e-Business Register, launched by the Ministry of Justice, allows online registration of companies in a few minutes using an ID card, Mobile-ID, or e-Residency card. Since 2011, Estonian companies have mostly been registered online, reducing the traditional five-day registration time to hours. Companies can retrieve tax arrears, file annual reports, update company details, and carry out due diligence by reviewing factors such as ownership, obligations, and regulations. A pioneering feature of this system is the Visualized Business Register, which enhances transparency by graphically representing the legal and financial relationships among companies (Buyan-Arvijikh, 2020). It is connected to the European Business Register and associated official documents and can be accessed for a subscription fee. Users can query prohibitions of companies in real time and track updates. This technology enhances transparency and ensures compliance, and also help tackle unreported labor, significantly contributing to the creation of a more environmentally sustainable, egalitarian, and resilient corporate environment.

e-Residency: Connected Economy

Introduced in 2014, Estonia's e-Residency initiative provides a new virtual identity for non-residents. Administered by the Estonian Police and Border Guard, it enables global entrepreneurs to sign up and operate EU-based companies online. e-Residents are issued a digital ID with PIN codes for secure entry, legal digital signatures, and encryption. They are able to register a company within a day, run it remotely, open a bank account, access international payment systems such as PayPal, and file Estonian tax (Särav & Kerikmäe, 2016)&(Kotka & Alvarez del Castillo, 2016). There are more than 25,000 entrepreneurs who utilize e-residency, including digital nomads, freelancers, and contractors. The initiative links individuals to Estonia's secure digital environment, and the European Union single market. The processing, which lasts between three to four weeks, is paperless and efficient (Poleshchuk, 2016). e-Residency, Estonia's pioneering initiative based on digital infrastructure, expands opportunities for entrepreneurs, reduces barriers to entry, and attracts investment, thereby stimulating economic growth and promoting social equity and resilience.

e-ID: Privacy, Access, and Empowerment

Estonia's e-ID system was implemented in 2002 and is one of the world's most sophisticated and comprehensive national digital identity systems. This governmental document is much more than a mere identification card, incorporating 384-bit ECC public key encryption, facilitating secure digital verification for many services (Murphy, 2022). Estonians utilize their e-ID to digitally authenticate documents, participate in online voting, view medical records, file taxes, employ e-Prescriptions, log into financial services, and travel throughout the EU, as it serves as both a valid travel identification and a national health insurance card. The chip on the card contains encrypted personal information, facilitating authoritative digital identification verification (Rahe, Tzitzelkov, Decheva, Stăvărache,

&Tsonev, 2021). It offers remarkable efficiency, allowing citizens to skip standing in lines at government offices and reducing paper-based operations.

The e-ID is the cornerstone of Estonia's digital government concept, as it facilitates nearly 100% digital access to public services and establishes trust in digital transactions. For the authorities, e-ID facilitates effective provision of services, reduced expenses, increased transparency, and prevention of mistakes in record-keeping. For citizens, it provides convenience, access at all times of day and night, and better data protection. The privacy is preserved by secure access logs, which enable a person to view who has accessed his/her details and when. The e-ID system is at the core of Estonia's approach towards sustainability, saving paper, carbon emissions in physical travel and bureaucracy, and setting up a culture of digital independence. With a population of over 1.3 million citizens, virtually all Estonian adults use the e-ID (Felt & LaRivee, 2025). The widespread adoption of the e-ID has established it as a central feature of everyday life in Estonia, introducing efficiency, security, and accessibility, cutting bureaucracy, saving time and money, and facilitating inclusive access to the most important services in the long term in a sustainable manner.

Smart-ID: Paperless Identity for a Connected World

Smart-ID introduces unprecedented convenience to the people by providing 24/7 access to financial services, healthcare services, and government services from any location worldwide with an internet connection. Smart-ID's security architecture includes end-to-end encryption, a blockchain-based Keyless Signature Infrastructure (KSI) for authenticity verification, decentralized data storage, and an access-controlled data pool. The system achieves double-layer security by requiring a first Personal Identification Number (PIN) for access and a second Personal Identification Number (PIN2) for transaction verification. Customers retain ownership of their data and are adequately informed of its use in compliance with Estonia's Privacy by Design policy (Oruaas & Willemson, 2020). It eliminates the necessity for physical infrastructure and, hence, is very well-suited for business travelers and distant workers. It improves customer happiness, lowers operating expenses, and streamlines digital onboarding for enterprises and governmental entities. Smart ID is a crucial element of Estonia's digitalization and sustainability strategy. It enhances customer satisfaction, reduces operational costs, and facilitates digital onboarding for businesses and government. Smart ID is an essential component of Estonia's digitization and sustainability plan. By avoiding the use of paper, it reduces energy costs related to face-to-face services, and facilitates online transactions, it achieves a more efficient, green, and digitalized world. Smart-ID had over 730,000 customers in Estonia, over 1 million in Latvia, and approximately 1.6 million in Lithuania as of 2024, with growing cross-border interoperability among the Baltic countries (e-Estonia, n.d). Smart-ID showcases the capability of mobile-first solutions in fueling an eco-friendly, future-proof digital universe.

e-Justice: Justice for All, Powered by Technology

In the early 2000s, Estonia commenced the digitization of its legal system, and by 2008, court proceedings were conducted entirely online. The intention was to improve the access to justice, reduce the cost of litigation, and improve the transparency and efficiency of the process. The system is built around the e-File central information system, which integrates courts, police, prosecutors, and prisons. By inputting data into a database a single time and enabling access from any location, redundancy and latency are eradicated. The public e-File portal enables citizens to request and track civil, administrative, or criminal

cases over the Web. After a claim is submitted, it can be reviewed and filed remotely by judges with access to case files through the court information system. Judges make decisions electronically, and court clerks arrange hearings on the Internet. Hearings take place through the portal, and after the electronically signed decision, it appears in the official electronic state gazette (Vatsa & Chhaparwal, 2021)&(Ahmed, et al., 2021). Court backlogs were reduced, case durations were shortened, and increased access was ensured, especially for individuals residing in rural areas. Through the digitization of records and hearings, Estonia has established a more expedited, transparent, and accessible judicial system. The extensive implementation of e-Justice has optimized the judicial system in Estonia. It has improved accessibility and transparency, streamlined legal processes, and reduced procedural barriers. Technology, in turn, has facilitated equal access to legal redress and reduced reliance on resource-intensive traditional court procedures. Technology-driven e-justice serves as the cornerstone of Estonia's e-governance, exemplifying judicial reform that fosters sustainable and fair development via efficiency and accessibility.

Data Embassy: Estonia's Sustainable Digital Backup

Estonia launched the world's first Data Embassy-a cloud-based extension of its key state information systems-in LuxConnect's Tier IV-certified data center in Betzdorf, Luxembourg. The project started as a concept back in 2015 and materialized through the signing of an agreement with Luxembourg in 2017. The project commenced in 2018, involving collaboration between the Estonian government and prominent business sector entities such as Cybernetica, Dell EMC, Ericsson, OpenNode, and Telia. The response addressed a serious concern. Estonia's digital government infrastructure could put critical national information at risk during a crisis or attack. In the absence of physical backups, preserving uninterrupted digital continuity became essential for national security. The data embassy has successfully addressed data loss, geopolitical concerns, and digital security, establishing Estonia as a global leader in digital sovereignty and cloud governance. A bilateral agreement with Luxembourg, based on Vienna Convention on Diplomatic Relations (VCDR) principles, provides Estonia's Data Embassy with specific legal protections (Robinson, Kask, & Krimmer, 2019), (Rice, 2019)&(Kaljund, 2018). This ensures Estonia's digital sovereignty and security, even beyond its boundaries. The stored data is protected by KSI Blockchain technology, which provides resilience and traceability. The data embassy provides inclusivity and sustainability through ensuring long-term access to essential digital services to all citizens and reducing resource consumption by having essential infrastructure outside the country. It also stands as a model for other nations seeking safe and stable digital continuity arrangements.

Digitization is Estonia's top priority. The nation has established higher goals for itself by embracing the National Digital Agenda for 2030, which came into force in 2021. The current focus is on connecting services to life events and creating features that automatically suggest the next steps (The Organisation for Economic Co-operation and Development, 2020).

Estonia's e-governance initiatives have helped the government achieve various Sustainable Development Goals. They have enhanced public health and well-being (SDG 3), increased access to quality education for all citizens (SDG 4), and encouraged economic growth and entrepreneurship (SDG 8). In addition, such digital initiatives have encouraged innovation and increased resilient infrastructure (SDG 9), helped reduce social and economic disparities (SDG 10), and ensured more secure, sustainable urban areas (SDG 11). They have also enabled responsible resource consumption (SDG 12) and strengthened the development of responsible, transparent, and inclusive institutions (SDG 16).

Multi-Pronged Approach to Cybersecurity

Estonians have enjoyed easy access to a range of e-government services for many years. With society, business, and politics becoming increasingly interlinked online, issues of cybersecurity have emerged. In countering these challenges, Estonia has assiduously built its cyber resilience. The nation has increased the capacity of its National Cyber Security Centre, enabling it to better identify threats, coordinate responses, and improve cyber capacities across sectors, thereby enhancing readiness and accelerating response to incidents (Kohler, 2020). Further, the Cybertest platform was built to provide free cybersecurity training to public and commercial enterprises. This has assisted more than 15,000 individuals to enhance their cyber awareness and reaction capabilities (Estonian State Information Authority, 2024). Development of initiatives like the Open Cyber Range and the Cyber Defense Unit enhanced resilience by enabling SMEs and volunteers to work on national security efforts. It imposed security standards on 3,500 companies, contributing to the improvement of digital protection across sectors. It also introduced public awareness initiatives to inform citizens and enterprises about cyber threats and good digital behavior (State Information Systems Authority, 2024). All the ministries were tasked with securing their digital infrastructure, reflecting a decentralized but integrated cyber defense framework (Kaska, Rebane, & Vaks, 2021). Furthermore, Estonia has been enhancing its international action on cybersecurity matters, with a focus on securing the critical infrastructure as well as generating confidence in digital (European Union Agency for Cybersecurity, 2024). These multilateral projects reflect Estonia's longstanding efforts to cultivate a resilient digital environment that upholds public trust, promotes equitable growth, and equips the nation to confront potential future global cyberattacks.

E-Governance Implementation Challenges

Estonia's effort to embed digitalization into its governance structure has been confronted with various challenges. One of them is the prevalent digital divide, especially between the older generations, who are least likely to have the digital skills. The skills gap has been a challenge to the mass take-up of digital government services (Leppiman, Riivits-Arkonsuo, & Pohjola, 2021). In addition, growing public interest in the security of children on the web and privacy of their information has caused other segments to be more reluctant to move into online environments(Estonian Safer Internet Centre, 2023). Lack of adequate awareness in the public regarding decision-making through AI, especially potential biases, black-boxing, and fairness, is another severe limitation. Thus, trust and satisfaction with online services have been lost among different segments of society. Estonia's strategic position within NATO's cyber coalition poses a threat of increased geopolitical and structural risks. Typically, potential threats from Russia give rise to serious vulnerabilities in the cyber system, including the risk of cyberattacks, internet shutdowns, and software failures. International digital connectivity also exposes ongoing issues, traditionally bedeviled by system compatibility issues that limit interoperability and detract from performance effectiveness (Laasme, 2012). From an economic perspective, small and medium-sized enterprises (SMEs) have been slow in embracing critical digital innovations, which remains the biggest impediment to general growth. Around 5.2% of Estonian companies use artificial intelligence, with 25.6% using data analytics, both rates lower than that of the European Union average. Digital competitiveness varies significantly across the private sector (Digital Strategy, 2024). To address these challenges, the Estonian government has unfolded a policy of managing risk that aims to balance technological progress with ethical conduct, good data protection legislations, and robust cybersecurity solutions. Despite such attempts, adopting

digital services in public administration still needs massive resources, and the economic sustainability of doing so for a small Baltic state with little financial resources is questionable.

DISCUSSION

Since the inception of e-governance initiatives, Estonia has strategically leveraged innovation and technology in public administration to improve the delivery of public services and to support its wider goal of fostering a more inclusive and sustainable society. It greatly expanded access to key public services through its pioneering e-governance framework, offering healthcare via the e-Health Portal with secure access to medical records and prescriptions, education through e-School that links parents, teachers, and students in real time, legal services through e-Justice that makes judicial processes more transparent and efficient, and democratic participation through e-voting that allows citizens to engage in elections conveniently and securely. Moreover, Estonia's e-Residency and Digital Nomad Visa take its digital governance global, promoting economic inclusion for foreign businesses. Early exposure to information technology, from primary school coding to national digital literacy initiatives, cultivated enduring digital resilience and adaptation among the workforce. Projects like the Data Embassy and blockchain-based data exchanges have redefined data sovereignty and national resilience. Sustainability is also top of mind in Estonia's approach-reduced use of paper, elimination of physical travel, and optimized performance of public services all reduce the carbon footprint and boost resource efficiency. The impact of these e-public service delivery is clearly evident: the citizens have benefited directly, services have been streamlined, and there has been increased use of digital platforms. This have enhanced societal engagement and sustainability, hence validating the value of governance through innovative and technology-driven initiatives. Estonia cannot sustain the performance of its e-governance without stronger cyber resilience, as it has made improving cyber resilience a top priority and adopted a multi-pronged approach to address these risks. Its successful digital implementations did not happen overnight. They were the result of decades of diligent effort, effective utilization of limited resources, and robust coordination between governmental institutions, technology innovators, and community organizations.

CONCLUSION

In the past two decades, Estonia has achieved significant progress in creating a more egalitarian and sustainable society. The findings of the study indicate that Estonia's e-public services are extensively trusted and utilized by its residents, which in turn has increased public participation, while also lowering costs and reducing environmental impact. These findings underscore how technology-driven government is steering the nation towards enhanced inclusivity and sustainability. It emphasizes that equitable practices, flexibility, strong inter-sectoral collaboration, proactive planning, and effective governance are crucial for enabling innovation- and technology-driven public administration to promote sustainable, inclusive, and future-ready societies. The nation's innovation- and technology-driven e-governance has furthered equitable development in accordance with the United Nations Sustainable Development Goals, including SDG 9 (Industry, Innovation and Infrastructure), SDG 10 (Reduced Inequalities), and SDG 16 (Peace, Justice and Strong Institutions). Estonia's example illustrates that when digital governance is founded on ethical principles and supported by robust institutions, it fosters openness, efficiency, and resilience, essential for attaining the SDGs. For countries seeking to transition to digital governance using innovation and technology, Estonia serves as a valuable example. The Estonian experience proves that success in building inclusive and sustainable societies does not depend on size or

wealth but on a definitive vision and a purposeful, inclusive approach to harness innovation and digital technology.

Limitations and Future Directions

This study relies on theoretical studies and secondary data sources such as peer-reviewed studies, government documents, and industry publications. Though this study offers an overview of how innovation and technology support e-governance for inclusive and sustainable development, it doesn't provide firsthand perspectives and comments by parties directly involved in the transformation process. It also does not adequately address criticisms or negative consequences related to Estonia's digital initiatives. The omission was intentional, because the main aim of the study is to showcase digital initiatives that could be applied elsewhere. There is ample opportunity for additional research on the subject. Future studies should aim to collect firsthand perspectives from policymakers, administrators, and citizens, and to conduct cross-country studies to analyze the scalability of Estonia's model. Studies on evaluating how digital initiatives maintain inclusiveness and sustainability over time would also be helpful.

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ADOLESCENT IDIOPATHIC SCOLIOSIS IN HIGH SCHOOL YOUTH IN MACEDONIA AND PUBLIC HEALTH

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Introduction: *Idiopathic scoliosis is a three-dimensional deformity of the spine with an unknown aetiology. Adolescent idiopathic scoliosis is a common disease with an overall prevalence of 0.47–5.2 % in the current literature. The female to male ratio ranges from 1.5:1 to 3:1 and increases substantially with increasing age.*
Method: *Descriptive study of the incident type, which includes 690 children of secondary school age from 15 to 18 years, with a clinical diagnosis of scoliosis, with the goal of radiological confirmation of the condition*
Results: *From the statistical analysis of a total of 690 respondents, high school students aged 15 to 18, determined that spinal deviation is present in all 690 respondents because they come with a referral diagnosis of scoliosis determined by clinical examination. The mild form of scoliosis dominating, which is present in 89.1%, i.e. 614 respondents, with a moderate degree of scoliosis 7.9%, i.e. 54.5 respondents, while the severe form of scoliosis is found in 3%. Scoliosis is more prevalent in female children, i.e. it is present in 65.8% of them compared to male children. In terms of age group, scoliosis is more prevalent in children aged 16-17 years compared to the rest by 1.3%. Kyphoscoliosis as a deformity is present in 41.3% of the respondents, it is more prevalent in the male population.*
Discussion: *Multidisciplinary and multisectoral approach is very important, it includes not only health workers and collaborators and education as a whole, but also the entire community should actively participate in the implementation of health promotion, with the goal of realizing the commitments of the WHO Declaration Health for all.*

Key words: adolescent idiopathic scoliosis, high school youth, radiology, screening, multidisciplinary approach

INTRODUCTION

In medical term, according to SRS (Scoliosis Research Society) scoliosis is defined as condition of side-to-side spinal curves that measure angle is greater than 10º. On an x-ray, the spine of a person with scoliosis looks more like an "S" or a "C" than a straight line. Although curvature of the spine is normal, scoliosis involves and sideways deviation and often includes

a rotational component, in which the vertebral bodies torsion along the spine axis (Addai D et all, 2020).

The human spine is a remarkable structure, balancing **flexibility and stability** to support posture, movement, and load transmission. Its structure is organized into **seven cervical, twelve thoracic,** and**five lumbar vertebrae,** followed by the fused**sacral** and**coccygeal**segments. The stability of the vertebral column arises from its **three-column architecture**, which provides both structural integrity and biomechanical resilience. The **anterior column** comprises the anterior longitudinal ligament and the anterior portion of the vertebral bodies; the **middle column** consists of the posterior wall of the vertebral body and the posterior longitudinal ligament; and the **posterior column** is formed by the posterior bony elements, including the transverse processes, articular facets, laminae, and spinous processes.

Each vertebra permits **six degrees of freedom** - three translational and three rotational - enabling complex spinal movements such as flexion, extension, lateral bending, and rotation. However, the range of motion is not uniform throughout the vertebral column; it varies according to regional anatomical specialization and biomechanical demands. Ultimately, the function of the spine reflects its structural design, demonstrating an intricate adaptation that balances mobility with stability to support posture, movement, and load transmission (Jor Spine, 2020).

Adolescent idiopathic scoliosis is with an unknown etiology. Approximately 30% of individuals with AIS have a family history of scoliosis.

Changes in the spinal column in scoliosis can be expressed as regular curvatures (deviations) of the axis in one plane or as curvatures combined with torsion of the vertebral bodies and rotation in the spine. (Filipović V.2003)

In relation to the age at which they occur, scoliosis is divided into: - infantile, occurring from 0 - 3 years of life, detected most often in the 1st year and manifesting as left thoracic curvature in the largest number of cases; - juvenile, occurring at the age of 4-9 years, most often detected around the age of 6, and manifested as right thoracic curvature; - adolescent, occurs most often between 10 - 14 years, that is, during the period of maturation of the skeletal structure. In most of the cases, 80%, it is present in the deviation and is most often manifested as right thoracic curvature, with localization from TH4/6 or TH11/12—L1. (Hitesh N et all, 2009)

In relation to the skeletal structure, scoliosis is divided into: functional (reducible) and structural (irreparable). Structural scoliosis, on the other hand, can be: congenital and acquired. (Adams J.C.,Hamllen D.L.,2001)

Acquired scoliosis is those that occur during life. In the largest number of cases (60-80%), the cause is unknown, so they are labeled as idiopathic. They occur during growth and worsen later.

According to the localization, according to Ponseti and Friedman (Ponseti I.V., 2003)), these are: lumbar, which occurs in around 24% of cases; thoracic, which occurs in around 22% of cases; cervicothoracic, which occurs in 0.5 - 1% of cases and combined, which occurs in around 37% of cases.

The prevalence decreases significantly as the severity of the curve increases. Curves measuring 10° to 20°: Female-to-male ratio is around 1.4:1. Curves measuring >40°. Prevalence is about 0.1%, and the female-to-male ratio is substantially higher at 7.2:1.

When children have a lateral curvature in the standing position, and in the lying position it is lost, it is not a true scoliosis, but a functional curvature of the spine or an irregular posture. On the contrary, this true scoliosis is always followed by structural changes in the spine and intervertebral discs.

Symptoms of scoliosis may include: noticeable changes in posture, asymetrical shoulders, one shoulder blade appearing more prominent than the other, an uneven waistline, one hip positioned higher than the other, one side of the rib cage protruding forward (Zaina F.et all., 2023) In most cases, scoliosis involves not only a sideways curvature of the spine but also a **rotation or twisting** of the vertebrae. This combined movement causes the ribs or muscles on one side of the body to extend farther outward than those on the opposite side.

When scoliosis is diagnosed, several factors need to be evaluated to determine the most appropriate treatment approach. One of the first considerations is spinal maturity, which indicates whether the patient's spine is still growing and changing. The degree and extent of the curvature are also important, as they show how severe the curve is and how it affects the individual's daily life. The location of the curve plays a role as well—thoracic curves, for instance, are believed by some experts to have a higher likelihood of progressing compared to curves in other spinal regions. Another key factor is the possibility of curve progression, since patients who develop larger curves before adolescent period are at greater risk of worsening deformity.

To confirm the diagnosis and assess these factors accurately, radiographic imaging is essential. X-rays are commonly used to visualize the vertebrae and joint outlines, helping identify other potential causes of pain such as infections, fractures, or deformities. Different imaging modalities have specific roles and indications in the assessment and management of adolescent idiopathic scoliosis (AIS). Radiography remains the gold standard for evaluating and monitoring scoliosis curves. Current guidelines emphasize minimizing the number of radiographs and limiting radiation exposure to the area of clinical interest. (Santiago FR, Ramos – Bossini AJL., Wang YXJ., Zuniga DL., 2020)

Today, the EOS® system represents an essential tool in modern scoliosis management, combining high diagnostic precision with a strong focus on patient safety through substantial radiation dose reduction. As a low-dose, bi-planar X-ray technology, EOS® captures full-body images in a natural, upright, weight-bearing position, allowing for accurate assessment of spinal alignment under physiological load. Its ultra-sensitive detector significantly decreases radiation exposure while maintaining excellent image quality. (Ilharreborde, B.2019)

The system is particularly valuable for the evaluation and longitudinal monitoring of scoliosis and other spinal deformities. Its markedly reduced radiation dose makes it especially suitable for children and adolescents who require frequent imaging during periods of growth. By providing precise measurements, reproducible imaging, and improved safety, the EOS® system has become a cornerstone of contemporary scoliosis assessment and follow-up care.

Three-dimensional (3D) ultrasound is an emerging technology with promising potential, but it remains in the early stages of development and currently has several limitations. Computed tomography (CT), once commonly used in scoliosis assessment, now plays a decreasing role and is being largely replaced by magnetic resonance imaging (MRI), particularly for diagnosis and preoperative planning. (Ng, S.-Y., Bettany-Saltikov, J. (2017)) Computed tomography (CT) scans provide detailed images of the spinal canal and surrounding structures and are particularly effective for examining bone anatomy. Magnetic resonance imaging (MRI) offers three-dimensional images of the spinal cord, nerve roots, and nearby tissues using strong magnets and computer technology, making it especially useful for detecting nerve compression, degeneration, or structural abnormalities. (Janicki JA, Alman B, 2007)

Magnetic resonance imaging (MRI) is used in the evaluation of scoliosis to obtain detailed images of the spine, including the spinal cord, nerve roots, and surrounding soft tissues, in order to identify or rule out any underlying causes of the curvature. An MRI is typically recommended for patients younger than 10 years, those with atypical or rapidly

progressing curves, or individuals presenting with neurological symptoms such as pain, weakness, or numbness. **(**McDonald, S. M., Teh, J. L. 2013)

While X-rays are essential for visualizing bone alignment and measuring spinal curvature, MRI offers a more comprehensive assessment of potential neural abnormalities, including conditions like syringomyelia or tethered cord syndrome, which may contribute to or mimic scoliosis.

Scoliosis management is determined by several key factors, including the patient's age, curve magnitude, and rate of progression. Treatment options range from conservative observation to complex surgical correction, with the primary objectives of preventing curve progression, alleviating symptoms, and optimizing spinal alignment and function. Non-surgical options include bracing to stop curve progression, physical therapy and exercises to relieve pain, and pain management with medication or injections. Surgery is reserved for more severe cases and involves fusing the spine to correct the curve. (Janicki, J. A., Alman, B., 2007)

Idiopathic scoliosis is a three-dimensional deformity of the spine with an unknown etiology. If left untreated, scoliosis can lead to progressive deformity, which may cause back pain, lumbar radiculopathy, cosmetic concerns, nerve injury, and even cardiac or pulmonary restriction. Patients with spinal curves exceeding 80 degrees in the coronal plane are at increased risk of developing shortness of breath. (Le Berre M et all, 2019)

Although surgical complication rates are generally lower than those seen in adult spinal deformity surgery, they still occur. A national dataset reported postoperative neurological injury in 0.9% of cases, respiratory complications in 2.8%, cardiac complications in 0.8%, infections in 0.5%, and gastrointestinal complications in 2.7%. Delayed infections involving surgical hardware are also relatively common. (Lonstein JE., 2018)

Globally, the prevalence of scoliosis varies from 0.11–5.2%, which can be attributed to diverse population characteristics, geographical influences, and etiological factors. Adolescence and female sex have been identified as important risk factors for scoliosis. The female to male ratio ranges from 1.5:1 to 3:1 and increases substantially with increasing age. (Zou Y et all.2022) Other factors such as body mass index (BMI), race, and lifestyle have also been linked to variations in scoliosis prevalence.(Li M. et all, 2024)

In the general population of children in the USA, scoliosis is represented by 1.5% where the angle of curvature is greater than 10 degrees. At female children scoliosis is 5 times more common. Scoliosis with lateral curvature of the spine greater than 10 degrees affects 500,000 adults in the USA (2 - 3%). Idiopathic scoliosis accounts for 65% of the total incidence of scoliosis. (Bollini G, Jouve J.L, Lecoq C, Garron E.,1999)

Research conducted in Europe and worldwide reports a prevalence of adolescent idiopathic scoliosis (AIS) ranging from 0.5% to 5.2%. However, these rates may vary depending on the screening methods used and the age groups included in the studies.(Wang S. et all, 2025)

Low back pain in adults is largely caused by late detected and untreated scoliosis, the prevalence of which is steadily increasing and worsened by lifestyle and work. In one study made in Germany, (Ploumis A., Transfledt E.E.,Denis F.,2006), it was determined that 60% of the causes of lower back pain in adults are scoliosis with a Cobb angle of 23 - 54 degrees, and in 10% when the angle is 45 - 63 degrees.

In Macedonia, according to data from systematic examinations of students in secondary schools in the 2022/23 academic year. (Stambolieva V., Tahiri J.2023) Spinal deformities are monitored in 14.1% (2330) of a total of 16524 examined students aged 15-18. (Figure 1, Source: IPH 2022/2023) That is, they are in first place in terms of the total number of determined pathological conditions. The total number of examined students in the next

2023/24 (Stambolieva V., 2024) with a systematic examination in secondary schools is 16574 students. (Figure 2, Source: IPH 2023/2024) Scoliosis is the most common health problem in this school year, recorded in 12.4% (2057) of the total examined. Compared to the data from primary schools from the same period, a higher incidence is observed in the high school population compared to the school population.

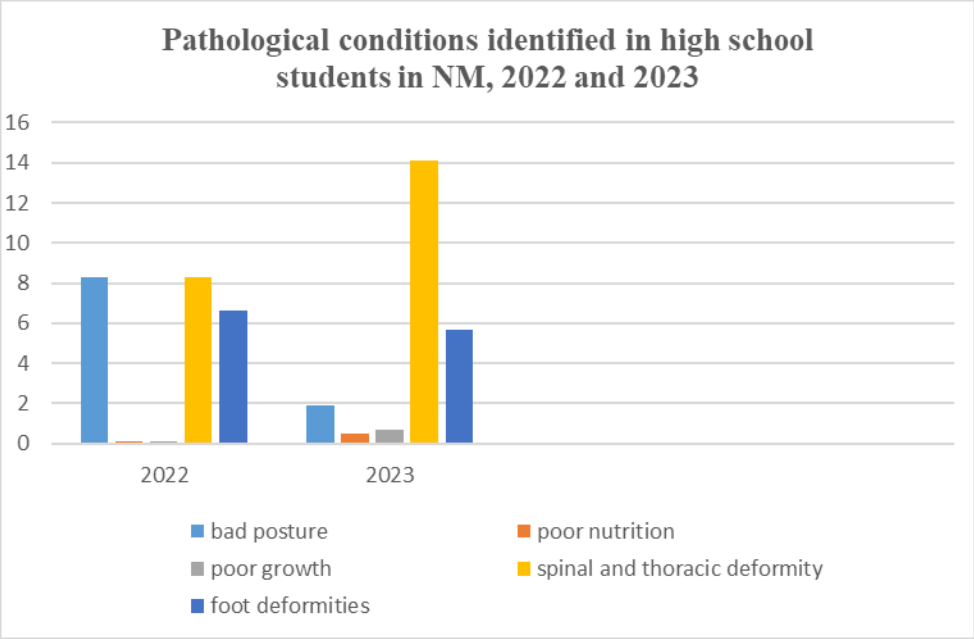

Figure 1. Pathological conditions identified in high school students in NM, 2022 and 2023 (Source: https://iph.mk/mk)

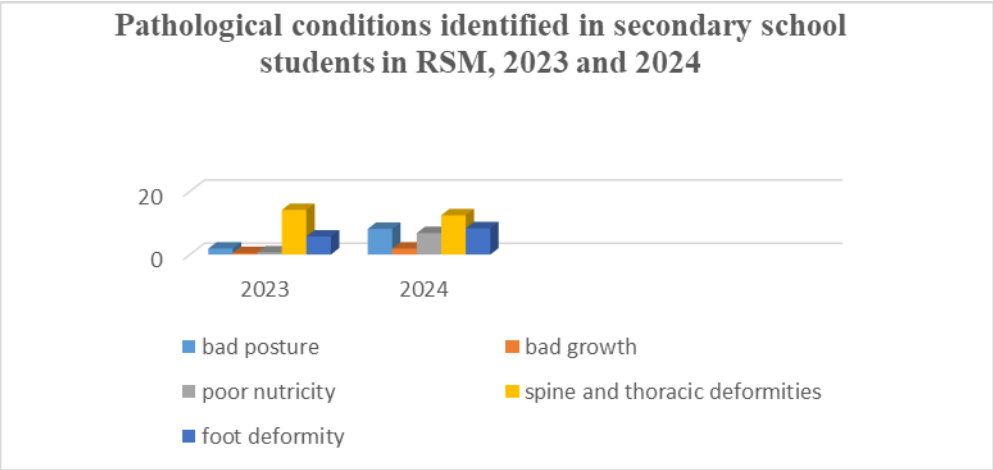

Figure 2. Pathological conditions identified in high school students in NM, 2023 and 2024 (Source: https://iph.mk/mk)

MATERIALS AND METHODS

The aim of this research is to determine radiologically diagnosed AIS in the high school population in the Republic of Macedonia, not only in terms of localization and size of the angle, but also to determine demographically in terms of age, gender, etc.

By design, this is a descriptive study. It was conducted at the Institute of Radiology - Skopje, using data from the electronic repository for performed examinations PACS system, over a period of one year. Our study included a total of 690 subjects, aged 15 to 18 years, with a clinical examination and diagnosis of scoliosis, which was confirmed in all subjects

through X-ray and MRI examinations. Radiological analysis is based on the measurement of Cobb's angle, which is done manually in our institution. Measurements of these angles are easily performed on plain X-ray radiographs. However, the situation is more complicated when these measurements have to be performed on MRI examinations.

The **Cobb angle** is the standard method used to measure the magnitude of a spinal curve. Originally developed for assessing curves in the frontal (coronal) plane, it can also be applied to sagittal plane deformities such as kyphosis and lordosis. (Figure 3, Source: Scoliosis X ray)

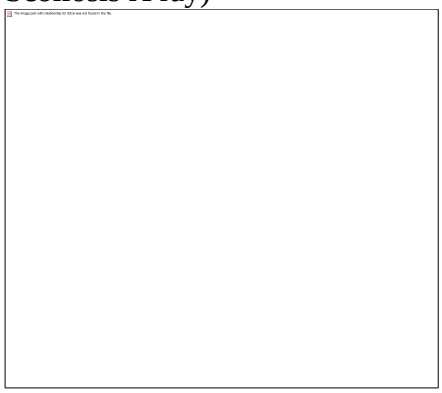

Figure 3.The Cobb method of angle measurement (Source: Scoliosis X ray)

When evaluating scoliosis, radiographs should ideally capture the entire spine on a single **posterior-anterior (P-A)** film to minimize radiation exposure to the chest, particularly the breasts. Even if only a coronal curvature is suspected, a **lateral film** is necessary to assess spinal rotation and sagittal alignment. Whenever possible, imaging should be performed in a **standing position** to reflect the spine's natural load-bearing posture; if standing is not possible, sitting is preferred over a supine position. For the P-A view, the arms should rest at the sides, while for the lateral view, they should be abducted 90 degrees to prevent obstruction of the spinal column. Although shielding of the pelvic area is common, **initial films should be taken without gonadal shields** to allow full visualization of the hips, pelvis, and proximal femurs. To **measure the Cobb angle**, the examiner first identifies the **upper and lower end vertebrae**—the most tilted vertebrae at the top and bottom of the curve that incline toward its concavity. The curve is classified according to the location of its **apex (vertex)** as thoracic, thoracolumbar, or lumbar. A line is then drawn parallel to the **superior endplate** of the upper end vertebra and another parallel to the **inferior endplate** of the lower end vertebra. Since these lines often do not intersect within the image, perpendicular lines (90°) are drawn from each. The **Cobb angle** is defined as the angle formed where these perpendiculars intersect - representing the degree of spinal curvature.

RESULTS

From the statistical analysis of data processing from a total of 690 respondents, high school students aged 15 to 18, It was determined that spinal deviation is present in all 690 respondents because they come with a referral diagnosis of scoliosis determined by clinical examination, with the mild form of scoliosis dominating, which is present in 89.1%, i.e. 614 respondents, with a moderate degree of scoliosis 7.9%, i.e. 54.5 respondents, while the severe form of scoliosis is found in 20.7 respondents, i.e. 3%. (Figure 4)

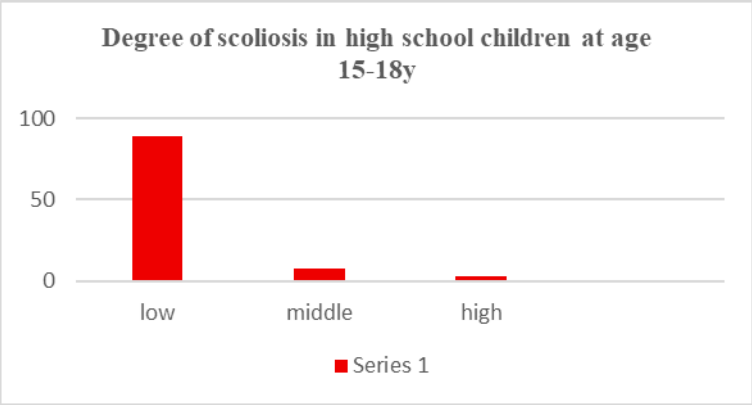

Figure 4. Degree of scoliosis in high school youth (Souce: Own depiction)

The gender structure of the respondents is represented by 38.4% male, i.e. 265, and 61.6% female, i.e. 425. (Figure 5)

Figure 5. Gender distribution and scoliosis in high school youth (Souce: Own depiction)

In terms of the side of the deviation, bilateral scoliosis is more common, occurring in 61.1% of the respondents, i.e. a total of 421.5 respondents. (Figure 6)

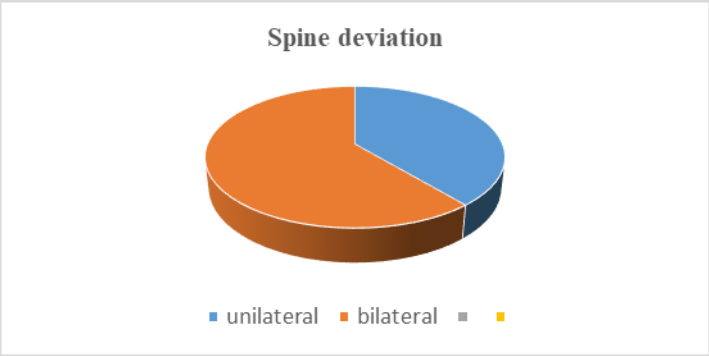

Figure 6. Spine deviation in school youth (Souce: Own depiction)

About localization, it most often affects the thoracolumbar part of the spine, occurring in 65.7% , followed by lumbar scoliosis, occurring in 26.1%, and the smallest percentage falls on thoracic scoliosis, i.e. 8.2% . (Figure 7)

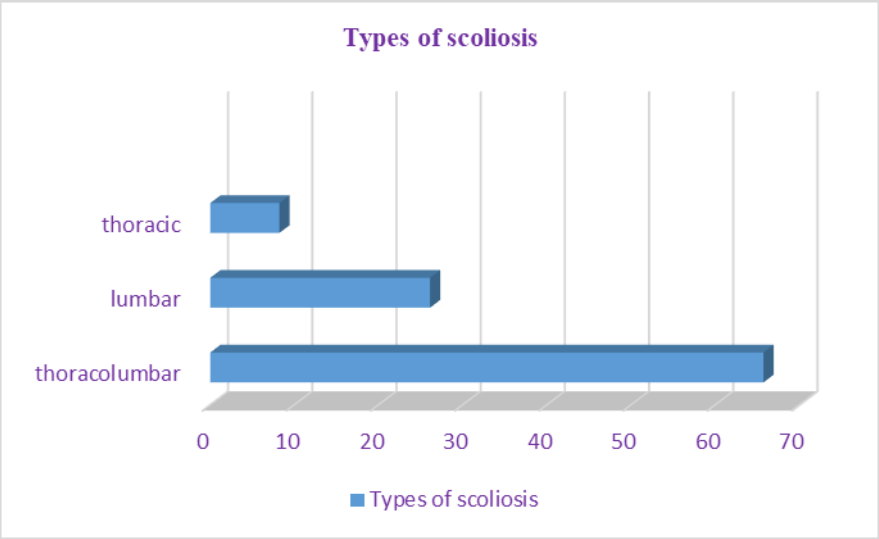

Figure 7. Types of scoliosis in high school youth (Souce: Own depiction)

The angle of curvature of the spine ranges from 10-78 degrees with an average value of 18.1+-8.9 degrees. (Tab 1)

Tab 1. Descriptive statistics of angle (Souce: Own depiction)

Parametars	Valid N	Mean	Minimum	Maximum	Std dev
Angle of deviation	690	18,1	10	78	8.9

Scoliosis is more prevalent in female children, i.e. it is present in 65.8% of them compared to male children. In terms of age group, scoliosis is more prevalent in children aged 16-17 years compared to the rest by 1.3%.

In relation to age groups, gender distribution and representation of scoliosis, in the youngest age group there are 142 female children against 63 male children. In the midle age group, there are 196 female children against 63 male children. And in the oldest group from 17 – 18 years old, there are 116 female children against 78 male children. (Figure 8)

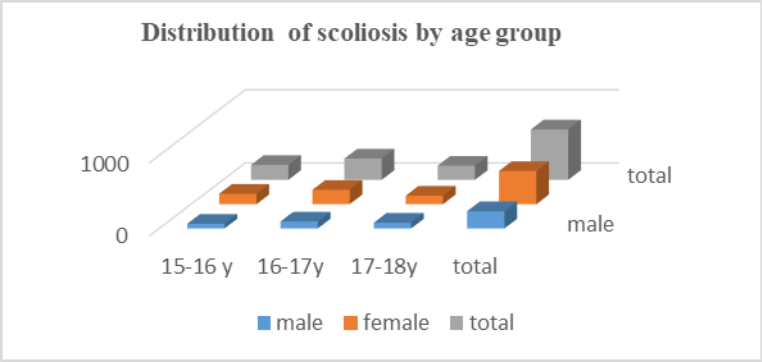

Figure 8. Distribution of scoliosis by age group (Souce: Own depiction)

Kyphoscoliosis as a deformity is present in 41.3% of the respondents, it is more prevalent in the male population. Ratio between male and female children and kyphoscoliosis in our study is 1,96:1. (Figure 9)

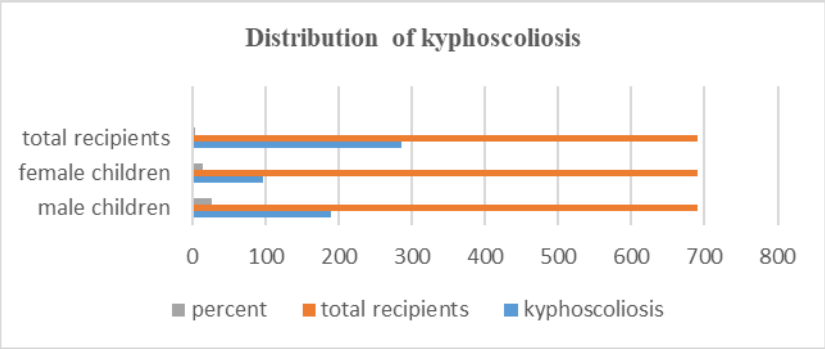

Figure 9. Distribution of kyphoscoliosis by gender (Souce: Own depiction)

The distribution of the respondents and the imaging technique that was carried out for the diagnosis of scoliosis, there are 239 male children and 277 female children on x-ray, or a total of 516 compared to 174 conducted on magnetic resonance, of which 85 male children and 89 are female children. (Figure 10)

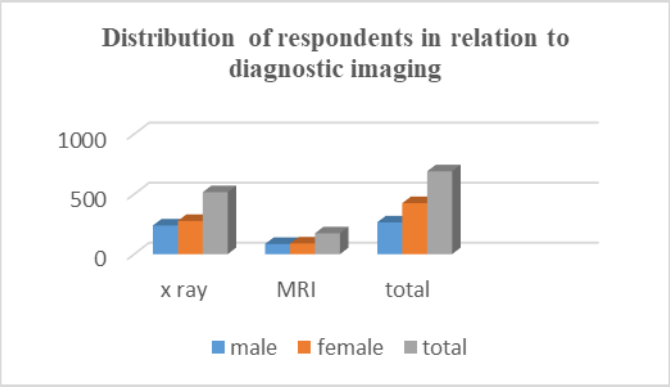

Figure 10. Distribution of respondents in relation to diagnostic imaging (Souce: Own depiction)

DISCUSSION

The results of this research showed that the prevalence of scoliosis is significantly higher in our country compared to developed countries. Distribution by gender and age shows that scoliosis is more prevalent in the female population and in the age group of 16 - 17 years. The results related to the types of scoliosis, the size of the angle and the location of the deviation confirmed that the most common is mild scoliosis, with an angle of less than 20 degrees and a thoracolumbar deviation, data that are more or less similar to those in published studies from different countries in the world.

The study by Daruwalla was carried out in Singapore and involved 110,744 children (60,167 girls and 50,577 boys). Children from 6 to 18 years old are included, but in the group that corresponds to our age population, only female children between the ages of 16 and 17 years old are included, and the prevalence of AIS is 3.12%. (Daruwala JS et all.1985)

Most studies of scoliosis in children and adolescents identify several factors that contribute to its high incidence and prevalence. These include **genetic predisposition, body mass index (BMI), insufficient physical activity, age, and the use of inappropriate school furniture**, among others. Some researches suggest that participation in asymmetrical sports - such as gymnastics, handball, and tennis - may increase the incidence of AIS.

However, modern lifestyles have greatly increased the risk of spinal problems. Prolonged use of smartphones and tablets encourages extended sitting and improper posture,

which in turn contributes to a growing number of spinal deformities among children. Therefore, the development of healthy lifestyle habits should start within the family, the cornerstone of society and be further reinforced through education and school-based programs.

Screening is a technique that has been popularized in the past few decades and is implemented in almost all developed and highly developed countries in the world. It is based on the use of tests with adequate sensitivity and specificity in terms of early detection of scoliosis and ensuring proper treatment of patients.

Untreated idiopathic scoliosis may lead to trunk deformities that compromise body aesthetics, reduce chest wall mobility, and decrease physical capacity.(Mackel C.E. et all., 2018) Therefore, early detection of idiopathic scoliosis is crucial as it can minimise the risk of idiopathic scoliosis progression, and can eliminate the need for surgical treatment.(Czaprowski D et all.2025)

The cost-benefit of screening is great, and the costs are low compared to the results that are achieved. The effectiveness of screening is also increased by the fact of increased awareness among children about this disease and easier acceptance of treatment methods. **School age** represents an optimal period to educate children about the importance of **healthy nutrition, physical activity, and overall well-being**. During this stage, children actively engage in social environments and increasingly shape their own lifestyle behaviors. A **varied and nutritionally balanced diet** supports growth and development, while **daily physical activity** contributes to psychomotor development, energy balance, and overall health. Early initiation of health education benefits not only the individual child but also the family and society, fostering lifelong healthy habits. Effective prevention requires commitment, resources, and effort, but its benefits are substantial. Crucially, **early detection of health risks** is a key component of preventive strategies, improving the likelihood of positive outcomes for both minor and chronic conditions.

In the context of **adolescent idiopathic scoliosis (AIS),** early detection and screening are critical preventive strategies. The **United States Preventive Services Task Force (USPSTF)** initially recommended routine screening for AIS in 1986, advising screening **twice annually in girls aged 10–12 years** and **once annually in boys aged 13–14 years**. Early identification in premenarchal girls was reported to **reduce the risk of curve progression by 20–30%** (USPSTF, 1996). Following evidence reviews, the USPSTF updated its 2018 recommendation, concluding that current evidence is **insufficient to assess the balance of benefits and harms** of routine screening in asymptomatic adolescents. While early detection may facilitate non-surgical interventions such as bracing, screening may also result in overdiagnosis, unnecessary imaging, and psychosocial stress. Clinicians are therefore encouraged to apply individualized judgment when considering AIS screening (USPSTF, 2018).

CONCLUSION

Technological advances in **diagnostic imaging, EOS imaging system,** have further enhanced scoliosis management. Collectively, these approaches demonstrate that **effective health promotion, early detection, and appropriate technological support** are integral to optimizing child and adolescent health. By combining **school-based education, preventive screening, and advanced imaging**, it is possible to foster lifelong healthy behaviors while minimizing the risks and consequences of common pediatric conditions, such as scoliosis.

Also, the continuous education and professional development of educational staff constitute a fundamental advantage for all students, irrespective of gender or age. Within this

framework, the adoption of a multidisciplinary and multisectorial approach is essential - one that encompasses not only health professionals and educators but also active involvement from the wider community. Such collective engagement is crucial for the effective implementation of health promotion strategies, ultimately contributing to the realization of the commitments articulated in the World Health Organization's *Health for All* Declaration.

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UNDERSTANDING TOURIST EMOTIONS TO FOSTER SUSTAINABLE DEVELOPMENT

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ABSTRACT

Introduction: *The global emphasis on sustainable development, guided by the Sustainable Development Goals (SDGs), has increased the need for strategies that protect cultural and natural resources, especially in tourism. This study addressed the challenge of integrating sustainable tourism with innovative management practices by analyzing tourist sentiments relating to the Monastery of Saint Naum, the most visited attraction in the Lake Ohrid Region in North Macedonia.*
Methods: *Methods involved sentiment analysis on online reviews from TripAdvisor collected untilAugust 2025 to assess visitor experiences and perceptions.*
Results: *Results showed predominantly positive sentiments focused on admiration for the site's natural beauty, historical and spiritual significance, and enjoyment of leisure activities such as boat rides and local dining. Negative feedback mainly concerned crowding and long queues, which slightly impaired visitor satisfaction.*
Discussion: *The study concluded that sustainable tourism management strategies should balance visitor access with conservation efforts, including controlling peak-time visits, investing in preserving the monastery's architectural heritage and natural surroundings, and promoting eco-friendly transport. Supporting local businesses within the monastery compound was also recommended to enhance visitor services and community benefits. These findings provide practical guidance for tourism managers, emphasizing the importance of understanding tourist emotions and aligning development with sustainability goals to safeguard the site's cultural and environmental integrity for the future.*

Keywords: sustainable tourism, sentiment analysis, visitor experience, tourism development, Ohrid, North Macedonia.

1. Introduction

Today, tourism stands as one of the most dynamic forces of global economic transformation, while its sustainability hinges on responsible governance and institutional coordination. This is particularly evidenced in regions of exceptional cultural and natural heritage like Ohrid Region. The global focus on sustainable development, guided by the Sustainable Development Goals (SDGs), has raised the need for strategies that protect cultural and natural resources, especially in tourism. As such, the SDGs encourage tourism to support inclusive growth, reduce inequalities, and promote sustainable consumption. In this line, effective strategies include conserving biodiversity, preserving cultural sites, and engaging local communities to ensure tourism benefits both people and the global environment. Adopting sustainable tourism practices helps safeguard resources while fostering economic and social development aligned with the global sustainability targets.

The Ohrid Region was designated as a mixed World Heritage (WH) site, first inscribed for its cultural value in 1979 (UNESCO 1979), and extended in 1980 to include natural heritage (UNESCO 1980). The Monastery complex of St. Naum (herein as Monastery) is one of the most visited tourist attraction in the Ohrid Region. It serves as an excellent case study for researching the complex linkages between cultural heritage preservation, the aesthetic and ecological value of natural landscapes, and the multifaceted pressure provoked by contemporary tourism. Its popularity among tourists and visitors makes it suitable for applying sentiment analysis (SA) to assess their perceptions, and at the same time, to inform whether its development aligns with sustainable tourism strategies. This particularly addresses SDG 11.4 and SDG 12.b. The SDG 11.4 highlights the importance of strengthening efforts to protect and safeguard the world's cultural and natural heritage, while the SDG 12.b encourages the development and implementation of tools to monitor sustainable tourism impacts (United Nations 2015). The importance of responsible consumption and production (SDG 12)emphasizes the necessity of sustainable resource use and minimal environmental degradation, i.e. "doing more and better with less"(United Nations 2015). In this context, sustainable tourism emerges as a vital tool to balance economic benefits with conservation efforts, empowering local communities and preserving destinations for future generations, and the application of SA is a valuable method for assessing visitor experiences and guiding sustainable strategies.

Linking sustainable tourism with innovative management practices is essential for addressing the complex challenges tourism faces today. Innovative management introduces new ideas, technologies, and approaches that reduce environmental impacts, preserve cultural heritage, and promote community involvement. By integrating sustainability principles with adaptive and data-driven management, the tourism sector can optimize resource use, enhance visitor experiences, and support local economies responsibly. This combination ensures tourism development is economically viable, socially inclusive, and environmentally sound, helping destinations achieve long-term resilience and sustainability goals.

Opinion mining based on sentiment orientation allows to understand perceptions and characteristics on groups, and to determine the credibility of content and motivations for posting reviews. In this line, this research examines the intersection of sustainable tourism and innovative management by analyzing tourist sentiments about the Monastery. The main objective is to identify tourist emotions and experiences through SA of online reviews posted on TripAdvisor. The goal is to provide practical guidelines for managers and policymakers on understanding tourist sentiments, improving service quality, and promoting sustainable tourism development. By aligning tourism growth with sustainability principles, the study also helps preserve the cultural and natural integrity of this attraction.

After the introduction, the paper presents an overview of relevant literature, followed by the methodology design. The next section details the results, along with a discussion of the findings. Finally, the paper offers the main conclusions.

2. Literature Review

Data mining and text summarization are earlier technologies than artificial intelligence (AI) that assisted to comprehend the experience of tourists after visiting a destination. Yet, with the rapid involvement of AI in all segments of everyday living, and with tourism becoming substantial part of the economy, tourism policymakers seek to understand more profoundly tourist emotional and experiential behavior. As, such, understanding opinions of tourists is important for further improvement when providing tourist services and developing other elements necessary for tourism activities. Academia has vastly explored SA as a part of a wider big data analysis approach and provided various models to interpret main factors that influence creating positive tourist image.

Ren *et al.* (2016) investigated the core attributes that lead to tourist satisfaction and found that tangible and sensorial experience, staff performance, aesthetic perception, and the location of the accommodation, are the most profound dimensions. Besides these attributes, there is research on other actions identified as dimensions that lead to tourist satisfaction (Lee and Heo 2009);(Xu and Gursoy 2015). In this line, Lee and Heo (2009) argued the importance of the corporate social responsibility practices when creating positive consumer satisfaction in hotels and restaurants. Such interrelation between responsible behavior and satisfaction is also elaborated by Xu and Gursoy (2015) who added the importance of creating and adopting sustainable practices in all aspects of tourist operating activities.

SA is also related to addressing the paradigm of sustainable development. Wei *et al.* (2025) focused on the intelligent analysis of big data and discuss the intersection of sustainable dimension and the public management innovation. They analyzed public sentiments and detected new innovative possibilities for creating powerful public management platforms that may create informative decisions based on sustainability dimensions. In this context, tourist attractions also require careful planning for sustainable and effective growth which often needs specific attention and big investments (Zakarija *et al.* 2024). These authors proposed a model that analyses sentiments of tourists that offer increase visitor engagement which can be easily replicated to other tourist destinations.

Having in mind that tourist attractions may have strong influence on the development of the destination, it is essential to acknowledge factors that provoke positive or negative opinions on tourists after the visit. SA on reviews on tourist attractions is extensively researched (An and Moon 2022); (Fang *et al*. 2022); (Luo *et al*. 2021); (Qin *et al*. 2022).

Deciding which attraction to visit, and which to avoid, is not easy for tourists when traveling for the first time to a tourist destination, and particularly when having limited time for sightseeing. In this context, Fang *et al.* (2022) provide a high-quality data set for reviews on tourist attractions that accurately provide valuable references and suggestions to assist when making a travel decision. Similarly, Luo *et al.* (2021) proposed a model to a case study on selecting tourism attractions with a multi-dimensional comprehensive evaluation system of indicators that analyzes large number of online reviews. Such SA-based model analyzes tourists' decision to visit particular tourist attraction, and at the same time ensures the effective management of tourism attraction managers.

Furthermore, An and Moon (2022) examined the contextual features of tourist attractions and designed a procedure to describe the process and offer a recommendation, which is particularly important when making final decision. The authors design a system that enables custom recommendations for tourist attractions even for supplement data that enables

various classifications. Similarly, Qin *et al*. (2022) offer a novel method based on SA, for ranking tourist attractions through online reviews. They elaborated the real feelings of the tourists after visiting and proposed a system that reduces the complexity of making a travel decision.

With regards to the case of North Macedonia, there are limited research on application of SA in tourism industry. Exception is noted in the work of Andreeski (2017) who investigated the important role to apply the SA for planning tourism development. He analyzed the guests' satisfaction with selected hotels and private accommodation in Ohrid and found much bigger satisfaction for villas. To our knowledge to this moment, there is no research on SA when investigating specific tourist attraction in North Macedonia, so this study fills this gap.

3. Methodology

Figure 1 presents the methodological approach applied for analyzing the online tourist reviews for the Monastery of Saint Naum in Ohrid (North Macedonia).

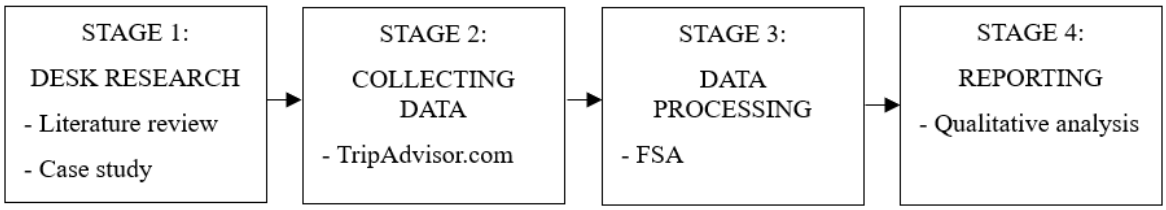

Figure 1.Research methodology
Source: Authors

Stage 1 involved desk research that incorporated review of literature on attributes that lead to tourist satisfaction, application of SA in tourism studies, and a case study background material.

Figure 2. Location of the Monastery of Saint Naum, Ohrid (North Macedonia)
Source: Google Maps (online)

Figure 2 presents the location of the Monastery, which is near the village of Ljubanista, 29 kilometers south of Ohrid, along the shores of Lake Ohrid. The Monastery was originally founded in 905 by Saint Naum himself, a disciple of Saints Cyril and Methodius. Although little remains of the original structure, the present church was rebuilt in the 16th centurywith frescoes dating from 1806 (Gould 2024). It is a remarkable cultural and historical site (Chausidis and Eftimovski 2023) and one of the most architecturally and historically significant religious sites in the country. Being among the earliest examples of Slavic

architecture and artistic expression in the region, the Monastery embodies the foundational legacy of Slavic literacy established by the medieval scholar and educator Naum. Having in mind that St. Naum was buried in a separate chapel on the south side of the Monastery, the site attracts many worshippers from various religions who come to payrespect to the relics of the saint. The broader environment embeds extraordinary view that evokes a profound sense ofharmony between the natural landscape and the rich spiritual and tangible cultural heritage. So, the location of the Monastery exemplifies an exceptional synthesis of ecological serenity and historical significance, making it a must-see tourist attraction.Located approximately 600 meters from the border with Albania, the Monastery is geographically positioned to facilitate circular tourism routes. This makes it highly accessible for visitors entering from Albania, highlighting its role as a gateway attraction that blends cultural heritage, natural beauty, and cross-border mobility within the Ohrid Region.

Stage 2of the research encompassed collecting data from the social platform TripAdvisor posted until August 2025. Out of total 1,057 data, only 671 were extracted as written reviews for identifying main factors that affect tourist experience and perception. This stage also involved data preprocessing and filtering. That means that the raw review text was organized before the analysis (Haddi *et al*., 2013) and transformed into meaningful features that the model can understand. After that, all residual text elements were eliminated as noise, like emoticons, special characters, symbols, repetitive punctuation (e.g., ellipses),tags, excessive whitespace, numerical values, etc. These components were removed from further modelling to prevent potential confusion or distortion when interpretating the results.

Data was processed in stage 3 with the Google Colab. After performing factor sentiment analysis (FSA) as a natural language processing (NLP) method, the results are presented as a dendrogram of review clusters (Figure 3) and FSA heatmap (Figure 4).

Stage 4 included qualitative analysis in terms of interpretation of data.

4. Results

Figure 3 presents the dendrogram of clusters derived from 44,382 words in 671 written reviews. 12 key topics were identified and organized in three clustered factors:

- Factor 1: 'Site' – This includes 'Monastery', and 'Lake'.
- Factor 2: 'Service' – This cluster includes 'Beach', 'Garden', 'Location', 'Food', 'Clean', 'Parking', and 'Price'.
- Factor 3: 'Surrounding' – This consists of 'Church', 'View', and 'Springs'.

Figure 4 presents factor sentiment heatmap which represents the scores in terms of intensity of the identified factors from the SA. The map enables discussion on how tourists that visited the Monastery perceive the attraction. Sentiment for each factor ranges from deep red color (representing strong dissatisfaction) to deep blue color (representing strong satisfaction). If the sentiment is represented with more frequencies, it means the greater intensity and influence of that factor.

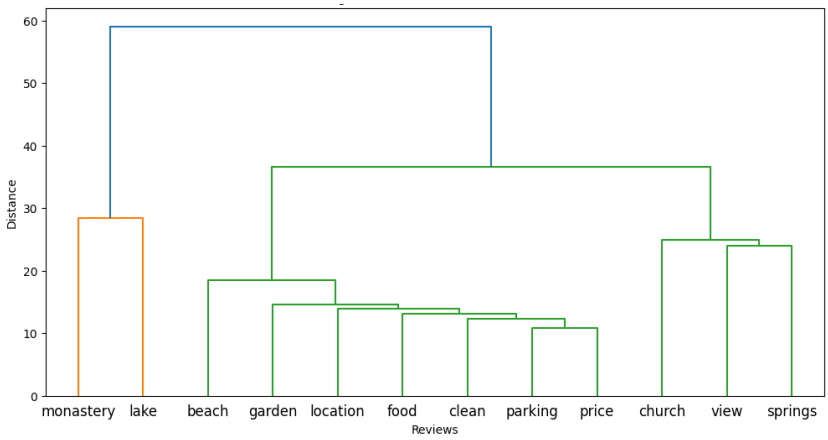

Figure 3.Dendrogram of review sentiment clusters
Source: Authors

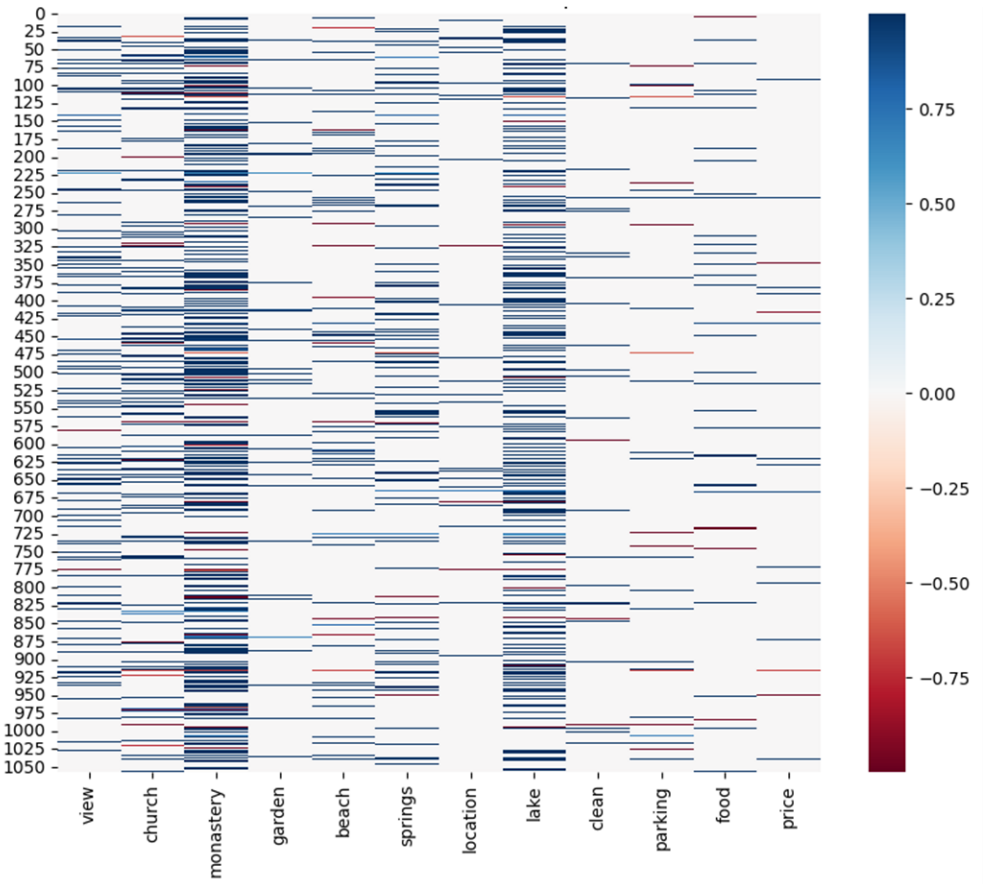

Figure 4.Factor sentiment heatmap
Source: Authors

5. Discussion and findings

The average numerical rating of 4.45 for all written online reviews is not sufficient to draw conclusions on tourist satisfaction. Therefore, SA enables more comprehensive interpretation of the results by providing more in-depth analysis. The research identified 12 factors, clustered into three main groups: 'Site', 'Service', and 'Surrounding', each consisted

of vectorized words as nouns representing closer insights on identified factors. It is interesting to note that all these constitutional elements refer to core attributes that lead to tourist satisfaction. Tangible and sensorial experience ('Site' factor), location ('Service' factor), and aesthetic perception ('Surrounding' factor) are generally discussed as the most profound dimensions of consumer comfort and enjoyment (Ren *et al.* 2016).

The 'Site' elicited as the most intensive factor whereas the monastery and the lake highlight the power of the nature as a precondition for sensorial and authentic experience (Wu and Yang 2023). The Monastery represents a significant cultural and educational landmark that has, for centuries, served as a spiritual nexus uniting people of diverse faiths through the veneration of St. Naum, revered as a miracle maker. Strategically situated on the shores of Lake Ohrid as the oldest lake in Europe (Leicher *et al.* 2024) and adjacent to the Galicica mountain range, both of which are protected under UNESCO, this site embodies a unique convergence of natural and cultural heritage. These attributes position the Monastery as an important tourist attraction in the country offering profound historical resonance, environmental significance, and cross-cultural accessibility.

The second most influential factor is the 'Surrounding' where tourists expressed strong emotions on the nearby scenery in terms of the extraordinary view and the breath-taking springs. Forming a boundary with the natural ambient describes strong relationship in the reviews, which conform with previous findings of Gu and Ryan (2008). The springs represent a rare and ecologically significant natural phenomenon, where crystal-clear karstic waters emerge from beneath the Galicica mountain and flow directly into the Lake Ohrid. The springs are protected for their ecological and spiritual value, further enhancing the site's appeal and contributing to the spiritual and ecological identity of the Ohrid Region. They are protected for their hydrological and environmental valueand are considered as one of the most pristine freshwater systems in Europe. Tourists enjoy rejuvenating experiences by an authentic boat rowing. On the other hand, the growing anthropogenic pressure caused by the increased frequency of tourists and waste pollution incompliance with the legal regulations for sustainable management of this attraction. Therefore, the National Park Galicica along with other institutional policymakers prepared a Draft Special Plan for the Management of the St. Naum site (PI National Park Galicica 2023).

Finally, the factor 'Service' is found as the least emotional dimension, suggesting that the beach, garden, food, parking, and price are not the priority triggers for visiting this tourist attraction. Yet, there is negative feedback mainly concerning crowding, long queues, and parking, which slightly impaired tourist satisfaction, as argued already by Xu and Li (2016). However, it is worth noting that a horticulturally landscaped pathway leads to a beach area with fine yellow sand and local restaurants as a space for relaxation and leisure. This setting complements the spiritual and cultural experience of the Monastery, enhancing the overall appeal of the site through its tranquil natural surroundings. The presence of such variations in tourist sentiments suggests further profound investigation into identifying strategic actions to safeguard the site's cultural and environmental integrity for the future. The necessity for managing its sustainable development with responsible tourist behavior implies adoption of sustainable practices (Xu and Gursoy 2015).

The SA revealed that visitors predominantly hold a positive perception. Nevertheless, the presence of neutral and negative sentimentsespecially those concerning overcrowding, environmental degradation, and insufficient infrastructurehighlights an urgent need for strategic planning and intervention. Key strategies include controlled visitor access during peak times, investment in preserving the monastery's architectural heritage and natural surroundings, and promotion of eco-friendly transportation options. Supporting local businesses within the monastery compound can further enhance visitor services while benefiting the community economically. By integrating these measures into a comprehensive

sustainable tourism framework, the region can protect the site's cultural and environmental integrity for future generations and stimulate local economic growth.

The global emphasis on sustainable development, guided by the SDGs, has increased the need for strategies that protect cultural and natural resources, especially in tourism.In that manner, strategic interventions should be aligned with the SDGs. Measures such as controlled visitor flow, preservation of cultural and natural heritage, eco-friendly transport, and support for local businesses not only address these concerns but also contribute to SDG 11 (sustainable communities) and SDG 12 (responsible consumption), ensuring long-term sustainability and community benefit.

6. Conclusion

The research undertook a SA that revealed 12 key topics grouped into three factors: 'Site' ('Monastery', and 'Lake'), 'Service' ('Beach', 'Garden', 'Location', 'Food', 'Clean', 'Parking', and 'Price'), and 'Surrounding' ('Church', 'View', and 'Springs').The factor sentiment heatmap indicated that while overall perceptions are positiveparticularly toward the natural and cultural settingthere are notable concerns related to service quality and infrastructure. These insights underscore the need for targeted interventions that align with sustainable tourism principles, including improved visitor flow management, investment in site preservation, enhanced service delivery, and support for local businesses. Such measures not only address visitor expectations but also contribute to long-term cultural, environmental, and economic sustainability in line with the SDGs.

The study concluded that sustainable tourism management strategies should balance visitor access with conservation efforts, including controlling peak-time visits, investing in preserving the monastery's architectural heritage and natural surroundings, and promoting eco-friendly transport. Supporting local businesses within the monastery compound was also recommended to enhance visitor services and community benefits. Such findings also provide practical guidance for tourism managers, emphasizing the importance of understanding tourist emotions and aligning development with sustainability goals to safeguard the site's cultural and environmental integrity for the future.

The study acknowledges several limitations. The SA was conducted on a relatively limited dataset, which may affect the breadth of insights. Furthermore, the analysis focused primarily on textual reviews, thereby excluding other valuable forms of feedback such as interviews, surveys, or observational data. Future research should consider longitudinal data collection, engage a wider spectrum of stakeholders—including local residents and tour operators—and examine the long-term effects of targeted sustainability interventions. Such approaches would enable a more holistic understanding of tourist perceptions and inform the development of evidence-based strategies aligned with the SDGs. In this line, the study recommends that tourism policymakers implement sustainable management practices that effectively balance tourist flow with the preservation of cultural and natural aspects of the attraction.

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INNOVATIVE APPROACHES IN ORGANIZATIONAL PERFORMANCE MANAGEMENT AND THEIR CONTRIBUTION TO THE SDGs

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ABSTRACT

This paper's aim is to explore innovative approaches to organizational performance management, and its contribution to the achievement of the UN Sustainable Development Goals (SDGs), with a focus on the economy in North Macedonia. The study employs a mixed-methods research design. The literature review provides the conceptual foundation, while empirical evidence is collected through surveys with structured questionnaires distributed to managers and executives, complemented by semi-structured in-depth interviews. Findings indicate that while awareness of sustainability is growing, organizations in Republic of North Macedonia often use performance measurement frameworks mainly for compliance purposes. Research results confirm that application of advanced performance management models leads to cost reduction, efficiency gains, improved reputation, and enhanced organizational resilience. The study concludes that embedding sustainability into performance management systems contributes not only to organizational success, but also to broader societal and environmental goals. Future research should focus on sector-specific implementation strategies and longitudinal studies.

Keywords: organizational performance management, sustainability management, SDGs, performance measurement systems, organizational success

Introduction

Ensuring long-term organizational success increasingly depends on integrating innovative performance management approaches with sustainability principles and the Sustainable Development Goals (SDGs). In transition economies such as North Macedonia, organizations face intensified competitive pressures, resource constraints, and stakeholder expectations, which amplify the need for performance systems that go beyond traditional financial indicators to capture economic, social, and environmental outcomes. At the same time, global frameworks like the 2030 Agenda and concepts such as the triple bottom line and sustainable performance measurement systems (SPMS) have created both opportunities and practical challenges for aligning organizational strategies with broader societal goals.

Despite the growing recognition of sustainability, many organizations still apply performance measurement frameworks primarily for compliance, reporting, or narrow

financial control, rather than as strategic tools for innovation and sustainable value creation. This gap is particularly evident in emerging economies, where advanced models such as the Balanced Scorecard, SPMS, and multi-criteria decision-making methods are only partially adopted and rarely linked systematically to the SDGs. The central problem addressed in this paper is the limited and often fragmented use of innovative performance management models to drive organizational success while simultaneously contributing to the achievement of the SDGs in the context of North Macedonia.The main objective of the study is to explore how innovative approaches to measuring and managing organizational performance—especially those that integrate sustainability dimensions—relate to and enhance organizational success in North Macedonia. More specifically, the research examines the extent of application of advanced performance management models, investigates their connection with key outcomes such as cost reduction, efficiency, resilience, and reputation, and analyzes how these models support or hinder contribution to selected SDGs. The study tests the hypothesis that the application of advanced and sustainability-oriented concepts and models of performance measurement and management is significantly associated with improved organizational performance and success.This research is significant for several reasons. First, it provides empirical evidence from a developing, EU-aspiring economy, offering insights into how organizations operationalize sustainability and SDG-related goals through their performance systems. Second, it contributes to the literature by linking organizational performance management, sustainability indicators, and SDG-focused frameworks in a single conceptual and empirical model. Third, the findings can support managers and policymakers in designing more effective, sustainability-oriented performance management practices that strengthen organizational competitiveness while advancing economic, social, and environmental priorities in line with the 2030 Agenda.

LITERATURE REVIEW

Relationship between organizational success, critical success factors, and organizational performance

The modern terms that describe the concepts of organizational success, critical success factors (CSFs) and organizational performance, have intertwined earthly relationships and are all in a certain way mutually related and each with an impact on a different aspect, and all together on the overall success of organizations. Persons who have responsibility in an organization, whether they are owners, top managers, directors, presidents and other management positions, it is good to have an understanding of the existence of these relationships, because in summary, they encourage and assist the process of long-term strategic goals and maintaining competitive advantage. Organizational success encompasses different elements and dimensions, but still interconnected, including financial performance, market share, customer satisfaction and employee engagement. Organizations that are successful have a common characteristic, which is to have the ability to adapt to changing environments, while incorporating and applying innovations and having long-term sustainability[1], along with strategic consensus in decision-making, also ensures that all parties are aligned and equally committed to the organization's goals. Such a climate of teamwork enables collaboration, innovation, and a sense of belonging, which are essential for success.[2] Organizational success also involves the application of strategic and structural considerations

[1]https://study.com/academy/lesson/organizational-success-factors-definition-quiz.html Accessed on: 08.04.2024
[2]Rahman, Farhat naz & Kanasro, Dr. Hakim. (2015). TEAM WORK: A KEY TO ORGANIZATIONAL SUCCESS. Canadian Journal of Political Science. Edition Vol 3. 87-95.

in everyday operations. Flexibility and the ability to innovate are key to maintaining success in an unpredictable environment, because changes that occur, and over which organizations have no control, must be taken into account in future organizational decisions. Strategies designed according to the nature of the activities provide a roadmap and a clear picture for achieving organizational success. The application of strategies adapted to the specific characteristics helps organizations cope with challenges and seize opportunities. [3]The multidimensional nature of organizational success, critical factors and organizational performance play a key role in the functioning of organizations in various industries and therefore organizations pay attention to their detailing. Critical success factors (CSFs) represent areas towards which organizations must focus their activities, but they are in a direction so that there can be a basis for maintaining long-term success. The relationship between organizational success and these factors is inevitable. If we define these critical factors, they translate into the most significant segments towards whichthe organization needs to be focused in order to meet strategic goals.[4] Due to the different nature of the activities of organizations, critical success factors are different, but they have in common that they have a scope that relates to effective leadership and management, effective communication, a highly qualified workforce, processes and customer satisfaction. Critical success factors play a role in achieving organizational success, as they have a significant function in managing projects of various natures. Clear objectives, effective planning, risk management and stakeholder engagement are key to the success of projects.[5]Furthermore, in terms of importance for business operations, the factors act in a positive direction on productivity growth and overall organizational performance.[6] In relation to competitive advantage, in order to effectively identify critical success factors, adaptation according to the organization's activity is important. In addition, the size of the organization has its influence, the level of years of operation, etc. A properly set strategy for identifying and relating these factors to the organizational context is crucial. All phases in the implementation of activities are the result of a certain phase of the management functions. Starting from the planning phase, critical success factors related to organizational, human, project management, quality and technical factors can contribute to organizational success. Also, factors related to processes, i.e. the importance of planning processes, directly affect success. With a proper understanding of critical success factors,Organizations can improve their performance by meeting strategic goals and also by gaining competitive advantage.[7] Organizational success is defined and expressed differently in organizations in the for-profit, non-profit, and public sectors. Organizations in the for-profit sector, striving to ensure profit in the organization, need to demonstrate adaptation skills in order to be able to cope with all the changes and influences that affect their daily operations. The organization as an entity also changes its meaning over time, so according to recent trends, a modern organization is conditioned as a "team of teams", which is focused at the core on the relationships and connections with which that for-

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profit organization interacts. A successful for-profit organization balances between the internal and external environment, and coordinates activities through organizational culture. The characteristics of a successful for-profit organization in the 21st century are an intertwined paradigm between organizational culture, strategy and structure, effective management and leadership, the level of communication, implementation of actions and their monitoring. Organizations in this sector face a high degree of uncertainty and constant changes. It is these changes that should cause organizations in the for-profit sector to constantly monitor changes and create opportunities for their business from them. Identifying areas for improvement and creating value for all stakeholders is the basis for sustainability in today's organizations. Another characteristic of successful profit organizations is that organizations that strive for sustainability must incorporate digitalization, artificial intelligence, and generally take advantage of the benefits of modern technology in their processes and operations. Effective [8]communication in profit organizations is also an important factor in building synergy and unity between internal units of the organization, enabling different sectors to function together and employees to understand organizational goals. Factors that affect successful communication are performance, both internal and external communication, i.e. between employees, managers, and between buyers and suppliers.[9] Modern profit organizations no longer measure success by annual economic results based solely on profit. A successful organization is one that fulfills its legal obligations within the specified deadlines, is financially profitable, successfully deals with stakeholders, and manages the actions of its managed people efficiently and effectively. In conditions of global competition, a changing environment, and the creation of new markets, the creation of management practices that will lead to success is necessary. Talent management, in conditions of a shortage of qualified labor, is the main focus of most profit organizations.[10]

Consumer mentality is changing and organizational performance is becoming a major support in the process of making the right decisions that support the changes that have occurred on a global level. The concept of resilience is becoming a current topic for organizations in the profit sector. The term has been associated in the past with the ability of a phenomenon to return to a previous state after a certain decline, to rise again. The term originates from the field of ecology, denoting ecosystems that have the ability to absorb changes and survive. Organizational resilience refers to organizations that can cope with the uncertainties of the environment.[11]

Success in public sector organizations is a multifaceted concept, due to the nature of its activity to provide quality services, to be effective and to have good administrative capacities, and on the other hand, multidimensionality also arises from its political inherence. The hierarchical structure, the more rigid way of decision-making, the increased time for quick reaction when necessary, etc. are aggravating factors when it comes to public sector organizations. One of the factors for the success of this type of organizations is the organizationalcapacity that is associated with organizational capabilities. Organizational capacities are associated with the existence of teamwork, commitment and personal

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development, management of employee performance and employees being a kind of representative of the population where they operate geographically. The strategy in this sector gives priority to improving the conditions for the quality of life of citizens, effective management between priorities and relations with local-central government, building partnerships with organizations from the business and non-profit sector to improve services, etc. Public management implies constant improvement of transparency and clear roles of functions, as well as control over resources and budgeting, factors that contribute to success, and mutually affect organizational capabilities. [12]Due to the peculiarities of the public sector, sometimes attempts to improve performance in the public sector have mixed and sometimes even undesirable results. The search for sustainable and high levels of organizational performance is constant. In addition to the factors that act, specific areas for improvement in the public sector are also identified, which are associated with profiling the so-called public manager and his desired characteristics, such as integrity, high ethics, etc. Customer commitment is in the spotlight and a general improvement in the performance management of the organization allows for a proportional increase in the quality of the workforce. The commitment of governments to these topics has created high-performance government organizations that add significant value to society. [13]Measuring and evaluating organizational performance is one of the prerequisites for success in public sector organizations. Controlled by the government, created to provide services budgeted by taxpayers, they have a series of legal regulations that they need to comply with. The so-called public control allows for a comparison of public organizations in similar fields. The focus should be on outcomes that are important to the community they serve. Measurement, evaluation and management of organizational performance is carried out in areas such as customer satisfaction, quality of service and access to services.[14]

Organizational success in the nonprofit sector prioritizes the delivery of their programs and services over the communities or causes to which they are committed. Measuring mission accomplishment can be subjective. In order to be successful, organizations of this type need to be able to define and measure the effectiveness and efficiency of their work. In general, effectiveness is presented as the relationship between the goals set by the organization and the outcomes that result from its actions, while efficiency is the ratio between organizational inputs and outputs. However, organizational effectiveness is a multidimensional concept that is reduced to more than one measure, namely the level of management effectiveness and program effectiveness, organizational capacity and organizational results. Also, the result of this effectiveness is associated with the body that evaluates it. In addition, the difficulty in quantifying the effectiveness of nonprofit organizations is associated with technical problems that are not so easy to measure, due to their basic concept. The assessment of effects,such as whether a neighborhood is a better place to live, etc. Evaluations of various programs also face this challenge[15] .

Non-profit organizations are challenged to satisfy multiple stakeholders and therefore have a range of expectations to meet. However, in addition to meeting stakeholders' expectations,

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[15]Verschuere, B. & Suykens, B. (2020). Effectiveness and Efficiency of Nonprofit Organizations. 10.1007/978-3-319-99675-2_116-1.

internal organizational requirements also need to be met, as well as providing conditions where the use of learning and development outcomes can be maximized. Also, the satisfaction of service users always welcomes innovations, which in turn lead to attracting additional and better use of available resources in order to achieve organizational goals.[16] Organizational success in nonprofit organizations is difficult to measure, as the generally qualitative nature of social impact, etc., is not easy to analyze. Stakeholder perspectives on what constitutes "success"can vary significantly, making evaluation efforts even more difficult.

Sustainable performance measurement systems [SPMS]

Regarding the concept of sustainability, several historical features influence its development. The first feature goes back to the 18thcentury, when Carl von Carlowitz introduced the term sustainability in the context of forest management.Economically, the same term is associated with the survival of interests in the use of capital and the emphasis on long-term impacts of current decision-making. The second feature of this concept emphasizes environmental protection and socio-economic development. The Brundtland Commission defined sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The third feature is related to the concept of sustainability, which incorporates the three perspectives: ecological, economic andthe social dimension. It is precisely the responsibility of sustainability management that is linked to long-term management and the creation of value that integrates these three dimensions. [17]Almost three decades ago, it was presentedthe famous so- called triple bottom line (TPL), as a concept that promotes awareness of the importance,the connection and mutual influence between economic, social and environmental factors. Simply put, it promotes the interconnectedness of the terms: profit, people and planet. According to the renowned magazine, The Economist, TPL is already part of the business lexicon, described as a way of measuring the financial, social and environmental performance of organizations over a certain period of time. The quest for value creation is constant, and the renewal of functioning is associated not only with economies, but also with societies and the biosphere.[18]

Evidence from organizational performance measurement systems that promote sustainability provides mixed signals. Case study documentation across the integration spectrum suggests that the degree of integration is low in more informal structures and higher in formal control systems. Management decisions also depend on the personal views and beliefs of senior management. Customer demands result in pressure on organizations to implement and measure the organization's sustainability decisions.[19]

According to Searcy Corporate sustainability measurement is a system of indicators that provide the organization with information that will help with short -term and long-term

[16]Bernal-Torres, César & Montes Guerra, Maricela & Turriago-Hoyos, Álvaro & Castro-Silva, Hugo. (2021). Organizational and social innovation in Non-Profit Organizations performance in the context of an emergent economy. Intangible Capital. 17. 73. 10.3926/ic.1731.

[17]Beckmann, Markus & Schaltegger, Stefan & Landrum, Nancy. (2019). Sustainability management from a responsible management perspective. 10.4337/9781788971966.00016.

[18]Elkington, J. (2018). Sustainability 25 Years Ago I Coined the Phrase "Triple Bottom Line." HBR https://hbr.org/2018/06/25-years-ago-i-coined-the-phrase-triple-bottom-line-heres-why-im-giving-up-on-it.

[19]Pencle, N. (2023) . 'The Interactive Effect of Cognitive Frame and Performance Measurement System Scope on Managers' Choice of Sustainable Suppliers', Journal of Management Accounting Research, 35(3), pp. 153–171. doi:10.2308/JMAR-2022-041.

management, control, planning, and economic performance, environmental performance, and social activities undertaken by the organization [20].

Having the right mechanisms in organizations is necessary to be able to adequately answer the question of whether they are sustainable, or more specifically, which of their products, processes, and services are truly sustainable. An approach is needed to measure economic and non- economic factors because they have an impact on the ultimate organizational performance. [21]

The methods that are applicable to measuring sustainability in organizations are numerous. Among the most widely used are the following databases, with their sub-indicators: The Kinder Lydenberg and Domini [KLD] Database, the Fortune Index, the Canadian Social Investment Database [CSID], and others.Also, another method for measuring sustainability is single indicators (e.g., pollution control performance, etc.), as well as an analysis of organizations' publications on this topic. However, they should be applied carefully, and when drawing conclusions, it should be borne in mind that single indicators provide an overview of only one dimension, and the analysis of publications may not be that reliable (organizations themselves tend to present themselves in a more positive light than they really are).[22]

One of the more modern methods for assessing sustainability is the decision-making process, based on multiple criteria (sustainability performance is to use multi-criteria decision making (MCDM), i.e. analytical hierarchy process (AHP); data envelopment analysis (DEA); principal component analysis (PCA) and others. [23] SPMS is a construct that enables the translation of the sustainable strategy into real measurements of organizational performance. This so-called construct is three-dimensional and consists of: a financially oriented dimension, a growth-oriented dimension and a dimension with an orientation towards socio-environmental protection. It is pointed out that if any of the dimensions is not analyzed, then the conceptualization is disrupted.[24]

SUSTAINABILITY INDICATORS

The modern way of life, the availability of options for a better and higher quality of life is reflected in the limited resources, climate change, energy-related problems and other factors that directly and/or indirectly affect changes in everyday lifestyles. They lead to an indispensable need to create conditions for sustainable development. As a concept, the term sustainable development originates from the United Nations (UN) back in 1972, in order to achieve a balance between economic growth with social well-being and environmental protection. Three important concepts that do not always complement each other in a straight line and the development of one concept may not have such a favorable impact on the development of the other, that is, economic growth may have a negative effect on the

[20]Searcy, C. (2012) Corporate sustainability performance measurement systems: a review and research agenda. Journal of Business Ethics, 107(3), pp. 239-253. http:// dx.doi.org/10.1007/s10551-011-1038-z.

[21]Petros Sebhatu,S. (2009) Sustainability Performance Measurement for sustainable organizations: beyond compliance and reporting.

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[24]Muhamad, Nurisyal & Auzair, Sofiah Md & Amir, Amizawati. (2016). Measuring Sustainability Performance Measurement System. Œconomica, Vol 12, No 3 ECONOMICA http://journals.univ-danubius.ro/index.php/oeconomica/article/view/3361/3316#:~:text=2.1.&text=As%20defined%20by%20Searcy%20(2012,activities%20undertaken%20by%20the%20corporation').

environment, but a positive effect on social well-being. In 2030. The Sustainable Development Goals Agenda launched further defines the activities that should be covered in terms of sustainability, through the three interconnected entities, representatives of the previously mentioned concepts: people, economy and environment. In summary, sustainable development focuses on a state that meets the needs of the present, in whole or in part, without compromising the ability of future generations to meet their own needs. When using sustainability indicators, the concept of a circular economy is inevitable, as one of the most important solutions for sustainable development.[25]The 2030 Agenda for Sustainable Development is the result of negotiations by international experts who ultimately present and set the sets of goals and indicators. The complexity of this agenda encounters obstacles in implementation, with particular emphasis on localization. The connection between the global and the local in real examples results in the fact that globally set goals can face challenges when localized, which, again violate the initial intention. Indicators that are previously set at a global level sometimes cannot be localized. Indicators for sustainable development goals (SDGs) are around 232 in number, so-called SDG indicators, defined by the Inter-Agency and Expert Group on Sustainable Development.As expected, the focus is on achieving environmental sustainability, technology to provide sustainable solutions, developing countries to motivate themselves and policy makers to contribute to increasing awareness of these goals. These indicators are investigated in a study, which can be an example for developing countries (localization in the Pacific) to investigate whether the indicators are relevant and how this type of countries adapt to the application of the necessary indicators set at a global level. On the other hand, this study also names the factors of well -being (in the Pacific Islands). These factors are related to several dimensions, namely: sustainability management, access to infrastructure,civic services and financial resources, health, access to natural and cultural resources, education, environment, knowledge, skills, values and connection with people andlocations.Measurement challenges are classified into several categories, related to indicators:[26]

- Focus /bias - this category is generated as a result of the indicator as a concept is specific and aims to focus on a specific phenomenon, on a single concept, i.e. on a single value system as opposed to local value systems. Local values and beliefs are not always aligned with global guidelines. The additional dose of bias is a real situation, namely bias towards a particular strategy or agenda which, on the other hand, implies the exclusion of others. Also, the lack of management in public activities leaves room for nonlinear implementation.
- Feasibility – indicators set at the global level and their relevance there, may not be equally relevant and feasible at the local level, for various reasons and resource constraints, both financial and human, but also shortcomings associated with a lack of commitment, but also shortcomings in data collection. Social norms do not always reflect accurate answers.
- Linkage with the target – indicator, there is also a possibility that it may not be adequate and sufficient to be successfully linked to the progress of the defined goals.

[25]Ngan, Sue Lin & Shen, How & Teng, Sin Yong & Promentilla, Michael Angelo & Yatim, Puan & Er, Ah Choy & Lam, Hon. (2019). Prioritization of sustainability indicators for promoting the circular economy: The case of developing countries. Renewable and Sustainable Energy Reviews. 111. 314-331. 10.1016/j.rser.2019.05.001.

[26]Sterling, Eleanor & Pascua, Pua'ala & Sigouin, Amanda & Gazit, Nadav & Mandle, Lisa & Betley, Erin & Aini, John & Albert, Simon & Caillon, Sophie & Caselle, Jennifer & Cheng, Samantha & Claudet, Joachim & Dacks, Rachel & Darling, Emily & Filardi, Chris & Jupiter, Stacy & Mawyer, Alexander & Mejia, Manuel & Morishige, Kanoe & McCarter, Joe. (2020). Creating a space for place and multidimensional well-being: lessons learned from localizing the SDGs. Sustainability Science. 15. 10.1007/s11625-020-00822-w.

- Scale - the indicator is a unit of measurement that is initially set to be significant at the national/global level, but local progress is not always aligned or in the same direction as the global/national one.
- Disaggregation - separation into multiple components - The indicator may be appropriate at the local level, but there is a possibility that it may not adequately convey important local characteristics and specificities.
- Social damages – An indicator set at a global level, although set as a result of a previous in-depth analysis, may be inappropriate for the local level and therefore measuring the indicator may cause the opposite effect from the desired one, i.e. social or cultural damage.
- Environmental damage - quite the opposite of the purpose for which these types of indicators are created, unfortunately, the indicators set may not capture negative environmental externalities and decision- making that relies solely on these types of indicators has the potential to cause unintentional damage to the environment.

The overlaps and inconsistencies that arise with this type of global indicators impose the need for constant adjustment and analysis. This phenomenon of global indicators being implemented locally may have a different outcome than desired. The awareness of managers for this type ofPotential differences that need to be adjusted at the local level should be a guide when implementing indicators of this type.

Several questions related to sustainability are raised about what should be protected, what are the boundaries and time frames, and also how to improve the situation, etc. With the help of sustainability indicators, an objective answer should be given as to whether things are getting better or worse. Numerous methodologies are used for various purposes and should provide support in the decision-making process.

The Planetary Boundary (PB) methodology is related to the stabilization of the Earth system, in which way it would be possible to function today, but with a dose of intention to create a basis for a sustainable future, not only for today, but also for our future generations. Several steps are defined and for each of them there are several indicators. This is a newer concept and the indicators are still in the testing phase. The methodology called Life Cycle Assessment (LCA) quantifies relevant emissions and consumed resources that cause changes in environmental and health impacts, as well as resource depletion problems associated with any products or services. This methodology is in compliance with the ISO standard (ISO 14040/14044) in order to check emissions from all life stages of a product or service. This type of methodology does not provide a solution whether a certain alternative is absolutely sustainable, but still provides information whether it has a positive impact on the environment.[27]

The specificity of sustainability indicators comes from the nexus between the developers of these indicators and those who need to apply them. According to one study, there are five categories of reasons for their use:[28]

- Instrumental: indicators that inform decisions that have an impact;
- Conceptual: catalyze learning and understanding;
- Tactical: substitution for action and change of criticism;
- Symbolic: ritualistic promise;
- Political: support a certain position.

[27] Dong, Yan & Hauschild, Michael. (2017). Indicators for Environmental Sustainability. Procedia CIRP. 61. 697-702. 10.1016/j.procir.2016.11.173.
[28] Bell, Simon & Morse, Stephen. (2018). Sustainability Indicators Past and Present: What Next?. Sustainability. 10. 1688. 10.3390/su10051688.

Of course, according to their description, the most influential categories are the instrumental and conceptual, while the rest, i.e. tactical, symbolic and political, can cause distraction from the real problem and do not bring benefits to society. Of course, the boundaries between the above-mentioned categories are not distinctive and often one category passes into another.

Innovation-Driven Performance Management Aligns with Multiple SDGs in Organizational Sustainability

Sustainability-oriented organizational performance management, when driven by innovation, directly supports several Sustainable Development Goals (SDGs), notably SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), SDG 4 (Quality Education), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Research shows that integrating innovative practices into performance management enhances not only economic outcomes but also social and environmental sustainability.

Innovation, Performance Management, and SDGs

Economic Growth & Decent Work (SDG 8): Innovation in business processes and technology adoption is positively associated with improved productivity, competitive advantage, and economic growth, especially when supported by management commitment and human resource practices. However, the direct impact of innovation on organizational performance can be limited if not paired with broader sustainability strategies.[29]

Industry, Innovation, and Infrastructure (SDG 9): Adoption of digital transformation, smart technologies, and eco-innovation is crucial for building resilient infrastructure and sustainable industrialization. These approaches are essential for achieving sustainable supply chain performance and contributing to SDGs[30]

Quality Education (SDG 4): Continuous professional development and innovative learning communities foster lifelong learning and skill enhancement, supporting a culture of innovation and aligning with SDG 4.[31]

Responsible Consumption and Production (SDG 12) & Climate Action (SDG 13): Green innovation, circular economy practices, and responsible innovation directly improve environmental performance, resource efficiency, and reduce emissions, supporting SDGs 12 and 13.[32]

[29]El-Kassar, A., & Singh, S. (2019). Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2017.12.016.

[30]Khan, S., Ahmad, Z., Sheikh, A., & Yu, Z. (2022). Digital transformation, smart technologies, and eco-innovation are paving the way toward sustainable supply chain performance. Science Progress, 105. https://doi.org/10.1177/00368504221145648.

[31]Krabonja, M., Kustec, S., Skrbinjek, V., Aberšek, B., & Flogie, A. (2024). Innovative Professional Learning Communities and Sustainable Education Practices through Digital Transformation. Sustainability. https://doi.org/10.3390/su16146250.

[32]Ooi, S., & Memon, K. (2025). Responsible Innovation, Circular Economy and Organisational Resilience: Investigating Multiple Pathways Towards Sustainability Performance. Business Strategy and the Environment. https://doi.org/10.1002/bse.70057.

Social Sustainability (SDGs 5 & 10): Performance management systems that integrate social equity, gender equality, and fair labor practices contribute to reduced inequalities and promote inclusive workplaces.[33]

RESEARCH METHODOLOGY

Research Objectives

The main objective of the research is to determine the advanced concepts and models that lead the measurement and management of organizational performance of organizations from different industries and contribute to achieving organizational success in them.

To identify the opportunities arising from the concept of sustainability related to improved organizational success.

In the theoretical part, the methods of analysis and synthesis were applied, supplemented with data from international literature, as well as with the views and insights of theorists and authors who researched the issues addressed in this paper. When conducting the applied research on the sample, the methods that arise from the specificity of the research problem, and relate to the qualitative and quantitative nature, were applied. The research investigates the interdependencies between the application of advanced concepts and models of measuring and managing organizational performance and organizational success and the concept of sustainability related to improved organizational success. The questionnaire was filled out by the management/managers/persons familiar with the decision-making process in the organizations where it was followed. The data in the research were collected based on the survey method with a structured questionnaire implemented on 154 respondents (organizations) from profit, not profit and public organizations in Republic of North Macedonia. 10 semi structured in-depth interviews were conducted in parallel. The respondents were from the profile of general director of foreign investments in the Republic of North Macedonia, human resources director, finance manager, heads of public enterprises and presidents of non-profit sector organizations. Some of the participants also answered the questions from the survey questionnaire.

Testing and results of the main hypothesis

The testing in the table examines the relationship between two categorical variables:

Null hypothesis (H0): There is no significant relationship between the application of advanced models and concepts for measuring and managing organizational performance and organizational success

Alternative hypothesis (Ha): There is a significant relationship between. the application of advanced models and concepts for measuring and managing organizational performance and organizational success.

Table no. 34: Testing the basic hypothesis using the chi-square test

χ^2 value	Degrees of freedom (df)	p-value
33,217>26,296	16	p=0,007<0,05

Since the p-value of the χ^2 test is 0.007, which is less than the significance level α=0.05, we reject the null hypothesis and conclude that there is a statistically significant relationship between the variables, i.e., there is a relationship between the application of advanced models and concepts for measuring and managing organizational performance and

[33]Zihan, W., & Makhbul, Z. (2024). Green Human Resource Management as a Catalyst for Sustainable Performance: Unveiling the Role of Green Innovations. Sustainability. https://doi.org/10.3390/su16041453.

organizational success. This is also confirmed by comparing the χ^2 value with the critical value of χ^2 for 16 degrees of freedom.

Special hypothesis

The application of the concept of sustainability in organizations is associated with new opportunities for improved organizational performance.

According to the respondents, there is a positive trend regarding the connection of the concept of sustainability with new opportunities for increasing organizational success. The respondent organizations are familiar with the concept of sustainability, are aware of its benefits and have stated that they use sustainability indicators. Sometimes the application is applied due to regulatory nature, i.e. fulfillment of legal, and thus mandatory requirements. On the other hand, the need to apply it comes due to the demands that the client has on the organization. Additionally, according to the feedback from the respondents, the application of the concept of sustainability is positively related to improving the reputation of the organization that applies it. Undoubtedly, this approach requires flexibility, adaptation and the application of innovative solutions to be implemented. Innovative approaches in the organization on a large scale are reflected in the organizational processes, products and services they offer. Indirectly, the implementation of sustainability leads to increased engagement, but also provides opportunities for the retention of talented employees, because it initiates the creation of a sense of belonging to an organization that fosters sustainability, but also social responsibility, in a broader context. The existence of a relationship between these two categories, the concept of sustainability and improved organizational performance, is also evidenced by the fact that the majority of respondents answer affirmatively about the connection and express a strong position on the mutual positive effect.

FINDINGS

- The application of advanced concepts for measuring and managing organizational performance are conducted once a year, most often with the mandatory financial status; most common non-financial indicator is related to the concept of sustainability.
- Under the term methods and models for assessing and managing organizational performance, respondents understand and include only indicators, analyses, and most often associate them with employee performance.
- The connection between the application of advanced methods and models and organizational success is realized through: reducing operating costs, improving financial performance and improving the sustainability of the organization, cost savings and improved efficiency.
- The most commonly used non-financial indicators are KPIs, self-evaluations, proprietary software, customer satisfaction, changes in public good policies, website traffic and Lean philosophy market research, sustainability-related indicators, number of active members, etc. Non-financial indicators are adjusted according to the sector from which the organizations come.
- Of the options offered, the most frequently used is the Strategic Measurement and Reporting Technique (SMART) Performance Pyramid, The Balanced Scorecard (BSC) and Sustainable performance measurement systems (SPMS). Other options include: Triple your growth potential - a program developed and implemented by Best Solutions LCC, Lean performance metrics and proprietary software.
- The listed factors that hinder the introduction and application of advanced and comprehensive models of measurement, assessment and management of organizational performance in organizations are the following: insufficient capacity and lack of

resources as a disabling factor, further insufficient organizational readiness and resistance to change.

- It can be concluded that respondents generally hold the view that the introduction and application of innovative and more complex models of measurement and management of organizational performance leads to more benefits. Sustainability of the organization, better organizational climate and data-based decision-making that leads to organizational success.
- Regarding the challenges that would be faced when introducing and implementing more complex and innovative models for assessing and managing organizational performance, the majority responded that resistance would be one of the biggest challenges (resistance from employees, management, general resistance to reforms and innovations); workforce, human factor, technical capabilities and training of staff, employment of young and professional staff, inflexibility of staff and education of employees as well as knowledge and lack of human capital to apply them; lack of resources, namely: costs, finances and the number of employees, sustainability, financial costs and the need for additional employment; challenges that are related in content to the application of models for measuring and managing organizational performance.

RECOMMENDATIONS

- **Capacity of organizations to implement the sustainability system:** to investigate the actual ability of organizations to introduce sustainable practices, with a focus on cultural, structural and financial aspects.
- **Long-term impact of sustainability:** to conduct long-term research that will measure the relationship between the implementation of sustainable practices and the achievement of organizational success over a longer period of time.

In conclusion, this academic paper has explored the vital role of the Sustainable Development Goals (SDGs) as a blueprint for global progress in the twenty-first century, highlighting their function in uniting diverse stakeholders around shared sustainability objectives. Through an examination of multidimensional frameworks such as the Sustainable Performance Measurement Systems (SPMS), and the triple bottom line, the paper underscores how holistic measurement approaches enable organizations and governments to evaluate both progress and gaps towards the 2030 agenda. The integration of critical success factors, key performance indicators, and advanced multi-criteria decision-making methodologies further demonstrates the necessity of evidence-based policies and dynamic managerial tools in sustainable development practice. The findings reflect that while significant advances have been made in sustainability awareness, the translation of SDG principles into actionable strategies requires continued innovation in data management, institutional capacity, and collaborative governance. The research reveals persistent challenges including indicator alignment, coherence across policy sectors, and the localization of metrics for different contexts, but also highlights best practices from both public and private organizations striving for measurable impact. Ultimately, this study asserts that effective SDG implementation depends on adaptive performance measurement systems and robust partnerships that promote accountability, transparency, and learning across all levels of society. In summary, achieving the SDGs by 2030 will require ongoing commitment to innovative measurement, interdisciplinary research, and strategic cross-sector engagement, ensuring that sustainability targets are not only aspirational, but also realistically attainable through informed leadership and continuous evaluation.

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NORMATIVE–LEGAL ANALYSIS OF THE PROTOCOL OF COOPERATION BETWEEN THE PPO AND THE MoI OF THE REPUBLIC OF NORTH MACEDONIA

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ABSTRACT

Introduction: *This paper provides a legal analysis of the provisions contained in the recently adopted Protocol of Cooperation between the Ministry of Interior (MoI) and the Public Prosecutor's Office of the Republic of North Macedonia (PPO) within the framework of criminal procedure.*
Methods: *The paper conducts a comprehensive legal analysis of legislation within the relevant legal field and also the Protocol's provisions, while also examining specific internal legal acts established between the two institutions.*
Results: *The analysis demonstrated that the Protocol contains certain ambiguities in the legislative text that need to be more precisely defined.*
Discussion: *By adopting the new Protocol, and considering the challenges faced in the past two years, both institutions have undertaken a substantial step towards overcoming divergences in their joint actions, with the overarching aim of ensuring that justice in the Republic of North Macedonia is administered at the highest possible standard.*

Keywords: Protocol, cooperation, criminal procedure, institutions

INTRODUCTION

Republic ofNorth Macedonia, in its strategic orientations, is committed to integration into European institutions, a process that entails comprehensive reforms in all spheres of social functioning, as well as the establishment of clear rules and high standards in the work of state institutions. The acceptance of European values within the justice system requires the adoption of new postulates, among which the protection and full respect of the human rights of victims, suspects, and defendants occupy a central position.

These reform processes, however, represent a complex and long-standing challenge for the state, which has been undergoing a difficult transitional period of transformation from one social order to another. This transformation necessitates the abandonment of the principles upon which the former common state was based and the adoption of new values, with particular emphasis on the consistent observance of the corpus of human rights and freedoms.

A significant segment of the reform efforts concerns the judicial system. In the past decade, North Macedonia has adopted new laws reflecting European standards, introduced changes in the competences of investigative agencies, and ensured harmonization with the practices and recommendations of European courts as well as with the provisions of international conventions. These reforms constitute crucial steps towards ensuring transparency and accountability—values regarded as essential preconditions for the successful implementation of justice reforms. A transparent criminal procedure, in which material traces and evidence are promptly and objectively presented to the public, where testimonies leave no room for ambiguity, and where procedural errors are minimized, represents a guarantee for the delivery of fair and independent judicial decisions.

An essential step in this process is the precise definition of the legal framework within which the investigative authorities operate, particularly in terms of their competences and mutual relations. With the adoption of the new Criminal Procedure Code (2010), substantial changes were introduced: the Public Prosecutor assumed a central role in the entire preliminary procedure, including the pre-investigation procedure, with broad powers and extended jurisdiction. On the other hand, the Ministry of the Interior (police) retained autonomy in investigating reported criminal offences and gained greater freedom for proactive engagement in cases, but under reinforced supervision by the Public Prosecutor.

The involvement of the Public Prosecutor in the initial stages of investigation, however, raised a number of questions that the Criminal Procedure Code could not fully address, particularly those concerning the modalities of cooperation and communication between the Public Prosecutor's Office and the police. Recognizing these challenges, the two institutions established joint working groups, whose efforts culminated in the adoption of the Protocol on Cooperation, first issued in 2023 and subsequently revised and reissued in January 2025.

The purpose of this paper is to analyze the provisions of this Protocol, to identify potential shortcomings and ambiguities in its text, and to propose solutions that could further enhance and strengthen the cooperation between the Public Prosecutor's Office and the police.

1. The role of the Public Prosecutor in Criminal Proceedings

Under the term Public Prosecutor, the Protocol refers to: the Public Prosecutor of the Republic of North Macedonia, the Higher Public Prosecutor, the Basic Public Prosecutor for the Prosecution of Organized Crime and Corruption, and the Basic Public Prosecutor (Protocol on Cooperation, 2025, p.3).

The Public Prosecutor is an authority whose rights and obligations in criminal proceedings are grounded in the principles of accusatorial procedure and official duty.

The principle of accusatorial procedure implies that criminal proceedings may be initiated and conducted only on the basis of an indictment submitted by an authorized prosecutor, meaning that the competent body (the prosecution service) is the one that decides whether proceedings will be initiated against a particular person for a committed criminal offence.

The principle of official duty, on the other hand, establishes the obligation of the competent authorities to act *ex officio* in cases where a criminal offence subject to mandatory prosecution has been committed. This means that criminal proceedings are initiated and conducted regardless of the will of the injured party or other persons, from the moment the competent authorities become aware of the commission of a criminal offence subject to prosecution *ex officio*.

In Macedonian legislation, the Public Prosecutor is defined as: *"a single and independent state authority which prosecutes perpetrators of criminal offences and other punishable acts established by law, and performs other duties determined by law"* (Law on the Public Prosecutor's Office, 2007).

From a procedural perspective, the Public Prosecutor constitutes a party in criminal proceedings, but not in the classical sense of a party representing solely its own interests. Rather, it simultaneously functions as a state authority entrusted with safeguarding the collection and evaluation of evidence, both against and in favor of the defendant.

In defining the position and role of the Public Prosecutor in criminal proceedings, Article 39 is of particular importance. It stipulates that: *"The fundamental right and duty of the Public Prosecutor is to prosecute perpetrators of criminal offences subject to mandatory prosecution"* (Criminal Procedure Code, 2010).

This provision reflects the guiding role that the Public Prosecutor is expected to exercise during the investigation, namely by directing the competent authorities—primarily the police—in detecting and investigating criminal offences, through the issuance of orders or instructions in relation to specific cases.

In connection with the above, it is important to highlight a recurring situation that arises in the practice of joint action between the police and the Public Prosecutor in our territorial jurisdiction – the territorial area of jurisdiction of the Sector of internal affairs Bitola, which we believe also occurs in other parts of the Republic of North Macedonia, particularly in the investigation of reported offences in economic crime.

Namely, the manner of reporting criminal offences related especially in the field of economic crime, in practice most often occurs through anonymous submissions or hearsay information, which generally means that the police initially dispose of scarce data regarding the committed offence. The allegations contained in such reports frequently leave police officers uncertain as to whether the report contains elements indicating the existence of a criminal offence at all. Consequently, it is a common practice for the police to forward to the Public Prosecutor, reports with bases for suspicion of having committed alleged criminal offences without undertaking the necessary operational verifications in report.

Upon receiving such notifications, the Public Prosecutor is then placed in the position of issuing instructions for additional checks to be carried out by the police, with the aim of obtaining a clearer picture of the allegations.However, this process of communication often, results in considerable loss of time, to the detriment of the overall quality of joint work in the case. These kinds of reports, in which the facts are not operationally verified by the police have a big probability to be false and that could lead to an unnecessary expenditure of the limited resources available to both the Public Prosecutor's Office and the Ministry of the Interior and the job may be characterized as a "hunt for shadows."

In this context, it is important to emphasize that the intention of the law – Criminal procedure code, should not be understood as positioning the police as a "subordinate" body to the Public Prosecutor, whose sole task is to inform and then await further instructions. On the contrary, the police should retain a proactive role in the investigation, striving to provide the Public Prosecutor with reliable and comprehensive information and evidence.

Recognizing the existence of these problems, the authors of the Protocol in Article 7 stipulate that: *"in cases of reports of criminal-legal events, the organizational unit of the Ministry shall verify the contents of the report in order to establish whether there are grounds for suspicion that a criminal offence subject to mandatory prosecution has been committed"* (Protocol on Cooperation, 2025).

As an example of overcoming such difficulties, reference may be made to the practice established between the Basic Public Prosecutor's Office in Bitola and Sector of internal affairs - Bitola. This practice involves the holding of regular working meetings between the

leadership of both institutions, which resulted in the adoption of *Recommendations and Guidelines for the Action of the Public Prosecutor towards the Judicial Police* in 2023, later incorporated and further developed within the Protocol on Cooperation.

To complete the overview of the role of the Public Prosecutor in criminal proceedings, it is necessary to highlight the provisions of the Criminal Procedure Code (CPC), which effectively placed the Prosecutor at the helm of the entire preliminary procedure: both the pre-investigative and investigative phases. This is most clearly reflected in the obligation of the police to mandatorily inform the Public Prosecutor about received criminal reports or information indicating grounds of suspicion of a criminal offence subject to mandatory prosecution (Article 282 ,CPC), as well as the duty of the police to comply with the orders and instructions issued by the Public Prosecutor (Article 282, paragraph 2, CPC).

The Protocol on Cooperation further strengthens the leading role of the Public Prosecutor through the provisions of Article 11, which foresee that the resolution of contentious or urgent situations in the investigation is to be decided exclusively through the issuance of instructions by the Public Prosecutor. Additionally, as the head of the proceedings, the Public Prosecutor may request that the Ministry of the Interior assign police officers for a limited period to meet the needs of a particular pre-investigative or investigative procedure (Article 13, Protocol of cooperation).

As an innovation introduced by the Protocol on Cooperation, Article 5 provides for a classification of criminal cases, whereby offences are divided into three categories:

- **Criminal offences under regular jurisdiction** – cases within the competence of the Basic Public Prosecutor's Offices and Prosecutor's Offices with extended jurisdiction;
- **Criminal offences under specialized jurisdiction** – cases under the competence of the Basic Public Prosecutor's Office for the Prosecution of Organized Crime and Corruption;
- **Complex criminal cases** – cases involving criminal offences under either regular or specialized jurisdiction, which, due to their manner of commission or consequences, attract considerable public attention, as well as criminal offences committed by three or more persons, those involving perpetrators connected to other states, or cases in which multiple criminal offences are interconnected.

This categorization of criminal offences was introduced in order to distinguish between urgent and regular reporting by the police to the Public Prosecutor. Specifically, for the first category of offences, it is considered that no urgency in action is required; thus, the police proceed in a regular manner, conducting necessary checks, gathering relevant information, and thereafter forwarding a notification to the Public Prosecutor in written form.
The second and third categories of offences, however, are regarded as more serious forms of criminal activity, deserving special attention and often requiring urgent action. For this reason, the police are obliged, upon receiving information on such offences, to immediately notify the Public Prosecutor, orally (Article 6, Protocol of cooperation).
Complex criminal cases are deemed to be those for which the Criminal Code of the Republic of North Macedonia prescribes a prison sentence of at least four years. As a specific subcategory, the authors of the Protocol also identify offences that may attract public attention or interest.

It should be emphasized that the formulation *"public attention or interest"* is particularly noteworthy, as it is simultaneously of general and broad character, leaving room for discretionary interpretation. It would therefore be advisable for future professional discussions to establish a more precise position on which criminal offences may fall within this category, and, if possible, to attempt their exhaustive enumeration. This would facilitate the obligations of police officers concerning the timely reporting of such offences.

2. The Role of the Police in Criminal Proceedings

The Criminal Procedure Code generally treats the police (here understood in accordance with the definition set forth in the provisions of the Law on Police) as an auxiliary body of the Public Prosecutor's Office yet with an important and irreplaceable role, particularly in the detection and investigation of criminal offences.

In this section, it is useful to briefly elaborate on the CPC provisions concerning the shared competences of the PPO and the police, viewed from the perspective of the PPO's leading role. For this purpose, we rely on the *Commentary on the Criminal Procedure Code* (Kalajdžiev et al, 2018).

The authors of the Commentary emphasize that under the CPC, the PPO is the head of the proceedings, with the authority to intervene at any stage of the investigation. The extent of such involvement, however, rests solely with the Public Prosecutor, who decides to what degree and in what scope responsibilities will be entrusted to the police in a particular case. In other words, it is at the discretion of the Prosecutor whether the police will be given "free rein" or will receive general or specific guidelines and instructions (Kalajdžiev et al., 2018).

Logically, the involvement of the PPO is expected in cases of more serious criminal offences, whereas in so-called "regular" offences (such as thefts, assaults, etc.) the police act autonomously, with limited engagement of the PPO. Importantly, we underline that the intention of the CPC is not to diminish the role of the police but, on the contrary, to enhance their initiative and autonomy, while strengthening their professional competence in regular proceedings. In practice, the police are expected to evolve into a type of "extended arm" of the PPO, by developing their own standard operating procedures and achieving specialization within their domain. Here, we primarily refer to the units of the criminal police, as they maintain the closest operational contact with the PPO.

The issue of police autonomy is also emphasized in the Protocol, whose Article 7 clearly stipulates that the organizational units of the Ministry of the Interior independently from the Public Prosecutor verify the contents of reports to establish whether there are grounds for suspicion that a criminal offence subject to mandatory prosecution has been committed. Along with informing the PPO, the police are to submit all evidence, information, and findings obtained during the verification process. Thus, the police retain independence in their actions, and the results of their verification are presumed to be objective and impartial.

From the foregoing, it can be concluded unambiguously that the foundation for effective cooperation between the PPO and the MoI lies in the quality of information collected by the police. Furthermore, Article 7 of the Protocol provides for the immediate notification (presumably oral) of the PPO when the police, upon completing their checks, obtain information indicating that there are grounds for suspicion that the alleged criminal act has been committed by a police officer. With this provision, the authors of the Protocol specifically single out such cases, as they require specialized competence - namely, criminal prosecution of police officers falls within the remit of a special department of the Public Prosecutor's Office for the Prosecution of Organized Crime and Corruption. Additionally, early involvement of the PPO in such cases is crucial in order to eliminate any potential future claims of bias or partiality in police handling of the matter.

The Protocol further highlights cooperation between the police and the PPO by allowing police officers working on a specific criminal case to directly seek guidance and clarifications from the Prosecutor, who is obliged to provide the necessary instructions or orders within the shortest possible time after receiving the report. This arrangement encourages and strengthens direct communication between the responsible Public Prosecutor and the investigator handling the case. Such direct interaction is indispensable for the proper

implementation of both the provisions and the spirit of the CPC, which requires a dynamic and trust-based relationship between the two central actors in any pre-investigative or investigative procedure.

In this context, we consider there to be a notable shortcoming in the provisions of the Protocol concerning the assignment of responsibility for notifying the PPO. The MoI is a large organizational structure, consisting of numerous units operating at both the national and regional levels. In practice, it is often the case that multiple units become involved in the same criminal event, which may lead to a lack of coordination regarding which unit is responsible for notifying the PPO about undertaken measures. This has produced situations where the PPO is simultaneously informed of the same case by several units (for example, a shift supervisor, a line inspector, and a duty inspector).Or conversely, existed situations where, due to poor coordination, the PPO is notified at all—or only belatedly—even in cases requiring urgent reporting.

Unfortunately, such situations are not rare. In the past, certain measures have been undertaken within the police structure to address this problem (e.g., orders issued by the Chief of Police Department), yet the generality of legal provisions remains, creating uncertainty among police officers. This vagueness is also present in the Protocol itself, since Article 7 does not specify the exact organizational unit of the MoI responsible for reporting to the PPO.

An attempt to provide greater clarity was made through the *Guidelines for the Work of the Judicial Police within the Bitola Regional Police Department* issued by the PPO Bitola in 2023. These Guidelines recommend that the officer designated for communication between the PPO and the Regional Police Department should be a police inspector who was present at the crime scene and thus has the most direct knowledge of the measures undertaken. We consider this recommendation to be a solid starting point for the further refinement of roles in investigative proceedings, as it reduces unnecessary communication between the PPO and third-party actors.

Finally, in relation to the role of the police in criminal proceedings, it is important to address the increasing involvement of the public in such processes. In recent years, it has become increasingly common for police officers to be filmed while carrying out official duties (such as searches), with these recordings subsequently being disseminated on social media, inevitably drawing public attention. We argue that such publication constitutes a breach of one of the fundamental principles of criminal procedure—confidentiality (as also stipulated in Article 19 of the Protocol). The materials recorded typically contain sensitive information (e.g., the identities of police officers). In this way, details of the investigation may be prematurely revealed to the public, potentially undermining subsequent procedural steps. We wish to stress that we do not advocate for any arbitrary conduct or abuse of authority by the police; rather, all irregularities must be addressed through proper institutional procedures. This is the only means of safeguarding the legitimacy of the investigative process.

CONCLUSION

The judicial system of the Republic of North Macedonia is currently undergoing a process of reorganization that is expected to be implemented in the near future. The participants in criminal proceedings are confronted with substantial reforms, the successful realization of which should demonstrate to the international community that the Republic of North Macedonia is a state governed by the rule of law, where the state itself acts as guarantor of the constitutionally protected rights and freedoms of its citizens.

The Public Prosecutor's Office and the police are direct participants in these changes. In recent years, both institutions have made efforts to improve their functioning and to enhance their joint actions. Amendments to the legislation governing criminal procedure were aimed at increasing the objectivity of all actors involved in the process. Neither the Public Prosecutor's Office nor the police can independently bear the full burden of criminal proceedings. On the contrary, a coordinated and cooperative approach is required. The greater the trust between these two institutions, the higher the quality and sustainability of the ultimate outcome of their work—the indictment.

Within this constellation of relations, the Protocol on Cooperation was adopted as a by-law, with the aim of overcoming certain difficulties that arise in practice, particularly regarding the obligation to notify the Public Prosecutor of a committed criminal offence. However, cooperation cannot be confined solely to the adoption of a single document; it must be continuously developed and strengthened. No document can definitively resolve all open issues. Therefore, we consider it necessary for joint working groups, composed of representatives of both institutions, to function on a permanent basis and to carry out their tasks in *bona fide*. Ultimately, mutual trust and a shared commitment to justice on both sides remain the key factors for the successful conduct of criminal investigations.

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SMALL STATE'S CAPTURED SUSTAINABLE DEVELOPMENT AS A CONSEQUENCE OF INSTITUTIONAL WEAKNESS AND POLITICAL POPULISM: WESTERN BALKANS CASE STUDY

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ABSTRACT

Introduction: *The purpose of this paper is to analyze to role of institutional and political frameworks, as a variable in the ongoing process of securing sustainable development. Authors thesis would rely on the explanation that the sustainable development is directly conditioned of the political and institutional frameworks in the case of small states with extremely limited political, economic, military and natural resources. Thus, the research question would be: What are the available instruments to small states in the process of securing development and sustainability?*
Methods: *In the methodological context the topic was chosen based on its topicality and because it contributes to the raising the discussion about the role of small states in the chapter of international relations where the sustainable development agenda is almost at the top. The goal is also to acquire new scientific knowledge, particularly in the context of determining the room for maneuver of small states in their foreign policy actions in the context of contributors to the already mentioned agenda. The authors will use basic analytical methods, such as content analysis of literature and documents and abstraction, to highlight the important characteristics that determine the foreign policy actions of small. Among analytical methods, specialization will also be used to pay special attention to the correlation between the sustainable development agenda and the foreign policy behavior of small states. When it comes to synthetic basic methods, concretization will be used to analyze the empirical example of the Western Balkans. On the other hand, induction will be applied in the conclusion section to establish a broader contemporary understanding about the small states in contemporary international relations based on the empirical example.*
Results: *Based on the available data, results and effectiveness of foreign policy activities, including internal political and institutional flows within the states of the so-called Western Balkans region used as an empirical example, results will provide explanation why the sustainable development agenda is "captured" from the perspective of their institutional and political dysfunctionality.*
Discussion: *From the theoretical perspective, authors will use the understanding of institutionalism in order to confront it to neoclassical thesis about the individual role in the*

decision-making process, that is quite important for understanding internal flows of small states, as well as foreign policy positioning, bearing in mind the fact that sustainable development represents a process composed of internal policies and foreign policy activism.

Keywords: small states, sustainable development, institutions, weakness, policy, populism

1. Introduction

Correlation between small states and sustainable development goals, as a topic de facto represents significant contribution to the international relations scholars. Why? Because it, as a such, opens double discussion paths: first, about the necessity for redefining the role of small states in the current chapter of international relations; second, to provide more clearer explanation about the characteristics of small states, thus categorizing them on small and relevant ones and those one, on the other side, with weak institutional infrastructure and political unpredictability.

In the second type of small states, authors have found the relevance for research the mentioned topic from two angles: domestic institutional framework as a pre-condition and foreign policy effectiveness as an instrument in securing sustainable development agenda on individual and global level. From such twofold perspective the research question would be following: do small states with vulnerable institutional infrastructure and weak political framework are able to perform effective national foreign policy, thus to contribute to sustainable development agenda and secure also it owns sustainability?

The objective of the paper is to explain the correlation between the performances of domestic institutional framework and political stability vis-a-vis the foreign policy activism of small states, as a core national resource in foreign policy positioning from the perspective of limited material or quantitative resources. The leading hypothesis would be that small states with weak institutional and political framework are unable to lead effective foreign policy activism, thus to reach foreign policy goals which, as a consequence endangers the national interests and captures the sustainability process.

From a theoretical perspective, the significance of the paper lies in the authors steps toward new understanding of small states in the current chapter of international relations, thus emphasizing the national qualitative resources as a variable in the foreign policy positioning. While, from the perspective of impact, the paper relevance lies in requests for concretization and deduction the general *Sustainable development agenda* in order to provide basis for sustainability strategies in accordance with authentic differences between subjects of international system.

2. Literature Review

If we analyze the Sustainable Development Goals from the perspective of goal number 16, we will find out that the sustainability is much more than an issue related exclusively on the quantitative variables. Although the public and media discourse in the context of sustainability is focused to measurable and qualitative characteristics, such as energy management, water exploitation, natural resources approach, migration issue, the labor market, factually there are numerous of quantitative conditions that should be met in the process of realistic, comprehensive and substantive sustainability. Goal number 16 titled "*Peace, justice and strong institutions*" represents not just destination that should be reached in the process of sustainability, but, in the context of this paper, it opens a "vertical", in-depth debate about the qualitative conditions or goals that should be met in the whole process. In, fact, there is a contradictory in the mentioned goal. Does it should be goal or it should be a kind of pre-condition for reaching other defined goals? Or it should be a priority goal, before

the process of processing other declared goals? Why authors are raising these questions? Because of the constatation placed within the goal number 16 which says that "corruption, bribery, theft and tax evasion cost developing countries 1,26 trillion dollars per year" (Goal 16 - Peace, justice and strong institutions, 2025). Further, referred data about the corruption is followed by concretization of followed concrete goals listed in the overall number 16 goal:

- "Promote the rule of law at the national and international levels and ensure equal access to justice for all.
- Substantially reduce corruption and bribery in all their forms.
- Develop effective, accountable and transparent institutions at all levels.
- Ensure responsive, inclusive, participatory and representative decision-making at all levels.
- Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime.
- Promote and enforce non-discriminatory laws and policies for sustainable development" (Goal 16 - Peace, justice and strong institutions, 2025).

Authors of the number 16 goal have touched the issue of institutional efficiency and effectiveness in the so-called developing countries, but still there is a lack of explanation about the aspects of responsibility, respectively to whom depends the process of establishing strong institutional framework, while, from the other side, what are concrete characteristics of mentioned developing countries. Identifying the responsible actors should be a kind of basis for further understanding and explanation the defined issue. Because, institutions, composed of personnel solutions, cannot reform by themselves, isolated of personal dimension. From the other side, precising and explanation the frame of "developing countries" provides basis for concrete actions on the ground to the sustainable development. For example, do the developing countries are challenged by material and qualitative risks which are mostly in the domain of economy and resources or those are also countries with qualitative domestic risks and threats, mostly institutionally and politically framed?

Aiming to comprehensive understanding the concept of sustainability from the perspective of small and weak states, using the domestic institutional and political flows in foreign policy positioning as a dependent variable, authors further will use the European Commission Annual Reports as an empirical example in the process of providing comprehensive threefold explanation: about the qualitative preconditions on the sustainability agenda, about the characteristics of small and weak states, about the factual relationship between foreign policy positioning from one side, and national/state interests in the context of sustainability, from the other side. Additionally, authors will analyze the national documents or strategies related to sustainable development in the context of their concrete measures related to internal and domestic critical challenges, risks and threats, including the proposed mechanisms for management and resolving. Basing the study on two pillars, concretely on the EU reports as an issue directly related to strategic foreign policy positioning and on the internal SDG strategies and documents, authors are providing comprehensive mosaic about the sustainability on the empirical examples of Western Balkans entities, listed in the group of developing countries.

2.1.EU reports

Following the methodological approach of concretization, the authors are using EU Commission Annual Reports about the so-called Western Balkans Six as a tool in the process of data analysis for two reasons: aiming the concretization and linkage between foreign policy positioning and sustainability, from one side; second, aiming to understanding the

causal relationship between internal (domestic) flows and the effectiveness in achieving defined foreign policy goals. Explanation between the dependence of sustainability on the foreign policy positioning lies in the understanding the national/state interests which are framed following the next thesis: preservation of national/state interests means sustainability. In practice it means that preservation the national/state interests contributes to securing the existence of the political entity composed of territory, effective government and integrated society. In such context, remembering that foreign policy goals are defined on the basis of national/state interests and at the same time serving as a certain goals in the continuous and permanent process of national/state interests preservation, we are by logic reaching the explanation that effective foreign policy activism leads to sustainability and contrary, lack of success in the foreign policy field, endangers simultaneously the foreign policy effectiveness, as well as overall state sustainability. Following the previous thesis, the analysis od EU Commission reports significantly contributes in the process of twofold explanation: the inter-dependence of foreign policy positioning and sustainability; second, the opportunities and consequences which internal/domestic flows have on the foreign policy positioning. Defined criteria analyzed in the EU Commission annual reports are on practical level proving the thesis about the dependence of foreign policy positioning, thus reaching foreign policy goals, by the internal/domestic challenges, risks and threats. Based on it, authors have justified the decision of usage the mentioned reports in the methodologic process of data analysis. Focused would be to the qualitative criteria such as rule of law, corruption phenomena, political and media and market regulations in order to asses structural (systematic, institutional, political) preparedness, respectively basis in the process of achieving proclaimed foreign policy goals which should on long-term basis contribute to sustainable development and sustainability.

Western Balkans actors are chosen empirical examples because of the fact that EU integrations are common regional determinator of all six states and political entities within the region. EU membership is placed on the postulate of strategic foreign policy goal for each of the political actor, while, from the other side, taking into account the level of multisectoral cooperation between EU and the regional actors, there is a justified explanation why the sustainability of these entities is strictly dependent of their foreign policy positioning. Second, because all of the actors (Belgrade, Skopje, Podgorica, Tirana, Sarajevo and Pristine) are categorized in the group of developing countries, so the authors got the opportunity to create a quite stable distinction between the concept of small states from one side, and the small states which are at the same time weak, in the systematic (institutional) proportions.

Concretely, based on the data analysis of EU Annual Reports 2025, all Western Balkans Six are facing pervasive internal/domestic challenges:

	Belgrade (European Commission/Serbia, 2025)	**Skopje (European Commission/North Macedonia, 2025)**	**Podgorica (European Commission/Montenegro, 2025)**	**Sarajevo (European Commission/Bosnia and Hercegovina, 2025)**	**Tirana (European Commission/Albania, 2025)**	**Pristina (European Commission/Kosovo*, 2025)**
Criteria						
Rule of Law	The independence and impartiality of the judiciary needs to be improved, both in the higher level courts and in the courts of first instance	The quality of justice needs to be improved; The efficiency of the justice system further declined	Montenegro must continue strengthening the effective accountability of the judiciary by fully implementing the improved legal framework adopted in 2024. Montenegro has yet to address the outstanding recommendations on strengthening the legal framework for disciplinary and ethical standards	Bosnia and Herzegovina is between an early stage of preparation and having some level of preparation and no progress was made on the functioning of the judiciary (Opinion key priority 6), including on addressing the findings of the expert report on rule of law issues (the 'Priebe Report')	The quality of justice needs to be improved. Measures are still needed to address the previously reported issues, including (i) the quality of initial and continuous training; (ii) the consistency of case law; (iii) the high number of judicial vacancies and insufficient amount of court staff; (iv) the lack of a modern integrated electronic case management system in courts and prosecution offices; (v) the quality, consistency and timely publication of judgments; (vi) the quality of court infrastructure; and (vii) reliability of statistical data.	The quality of justice needs to be further improved. The few high-profile cases on corruption and organised crime which were finalised during the reporting period, including former EULEX cases, mostly ended in acquittals or low sentencing; There are systemic challenges regarding the handling of serious crime and gender-based violence cases, notably linked to inefficient prosecution, deficient indictments and judgments, and inconsistency in sentencing practices
Corruption	The fight against corruption track record should be improved for both high-level and non-highlevel cases. Significant challenges persist, particularly in addressing high level cases. The number of final convictions in corruption cases high-level in 2024 decreased compared to previous years	Weak judicial transparency and prosecutorial performance continue to hinder the effectiveness and integrity of proceedings in high-level corruption cases	Montenegro is moderately prepared in the fight against corruption; Further efforts are needed to ensure full enforcement and alignment with several outstanding GRECO, Venice Commission and European Commission recommendations	The poor functioning of the judicial system continued to undermine citizens' rights and the fight against corruption.	Corruption remained widespread across vulnerable sectors, affecting both the public and private spheres. The institutional framework for prevention of corruption continued to have a limited impact and coordination with law enforcement remained weak. Shortcomings regarding transparency	Despite the pronounced political commitment to enhance anti-corruption measures, there is no coherent approach to it. To effectively fight corruption at all levels, Kosovo needs to make better use of existing anti-corruption legislation, including the Law on extended powers of confiscation

					and effectiveness of asset declaration checks still need to be addressed	
Political and Media environment	The incident and the aftermath have further deepened the polarisation in Serbian society; Parliament's effectiveness and oversight function remain hampered by the low frequency of sessions and the lack of genuine political debate; There was backsliding during the reporting period as the environment for journalists, media professionals and outlets seriously worsened	The enabling environment for the media's free, independent and professional operation needs to be improved; Political polarisation in Parliament persisted, delaying the adoption of important reforms and several long-overdue appointments	Social polarisation continued during the reporting period; Montenegro and its democratic institutions remain fragile and vulnerable to political crisis and potential institutional blockages; Although public authorities widely condemned acts of violence against journalists, instances of strong verbal attacks on the media and civil society representatives by public officials and political parties, including senior figures from the security and defense sector, have continued	The general framework for elections requires substantial reforms. Constitutional reforms are needed to ensure political equality and non-discrimination for all citizens. Electoral integrity needs to be improved, in line with recommendations of international bodies. Political parties should respect the independence of the Central Electoral Commission (CEC); No progress was achieved during the reporting period, including in guaranteeing freedom of expression and of the media, and the protection of journalists. Bosnia and Herzegovina continues to experience deep stagnation in media freedom, with worrying signs of deterioration. The financial sustainability of public broadcasters is ever more in danger. A countrywide network was set up to monitor cases of violence against	Political polarisation, lack of genuine political dialogue and clashes between the ruling majority and parts of the opposition continued to affect Parliament's activity, while public consultation processes remained limited. Parliament is also hampered by limited oversight over the executive, while the politicisation of parliamentary appointments to top positions in constitutional bodies or independent institutions established by law remains a serious issue; The situation remains largely unchanged, with media independence and pluralism continuing to be affected by the overlap of business and political interests, the lack of transparency of financing sources, the high concentration of media ownership, intimidation and precarious working conditions for journalists	Disagreements, polarisation and lack of cooperation between political parties prevented significant progress on EU-related reforms; Polarising language against opponents continued to be used in political debates; The media environment remained polarised, with some outlets accused of partisan bias and the IMC failing to act on media violations during the campaign due to a lack of decision making quorum

				journalists.		
Market regulations	The state has significantly intervened in the product markets. The government announced in August 2025 a major new intervention into the domestic trade of many basic goods, taking effect abruptly on 1 September 2025 for the following 6 months, with no meaningful prior consultation with stakeholders	The existence of a functioning market economy is endangered due to fact that government did not progress on key reforms	Montenegro has made some progress and is between a moderate and a good level of preparation in developing a functioning market economy. Economic growth slowed down amid weaker tourism exports in 2024 and the first half of 2025	Bosnia and Herzegovina is at an early stage of preparation – and there was no progress during the reporting period – in establishing a functioning market economy. Economic activity remained resilient despite a deteriorating political situation, with GDP growth slowing down to 2.6% in 2024, and to about 1.7% in the first half of 2025	The business environment also remains affected by weaknesses in the rule of law, informality and limited access to finance for SMEs, particularly farmers. Bureaucracy and lengthy licensing procedures, combined with problems of consistency in case law, create burdens for businesses	Large infrastructure gaps limit Kosovo's full economic potential and output; Despite recent efforts to diversify the energy supply and increase efficiency, the energy sector remains a key obstacle to economic growth; The private sector is dominated by small firms which still facing difficult access to finance
Overall: All Western Balkans Six from the perspective of European Commission Annual Reports are facing with prominent and pervasive domestic structural challenges, risks and threats which are burdening the process of effective foreign policy positioning, thus reaching the defined foreign policy goals. Selected structural challengers, risks and threats in the table represent a kind of mosaic for understanding the domestic/internal obstacles that case study actors are facing both, in the context of foreign policy effectiveness, as well as in the context of sustainability. Concretely, from institutional and political perspective, both, rational foreign policy activism and sustainable development are "captured" as a consequence of the lack of will and reliable mechanisms for managing presented disputes.						

2.2.National SDG documents and strategies within Western Balkans framework

Belgrade: In the document "Serbia and Agenda 2030 Mapping the national strategic framework in the context of sustainable development goals" there is a chapter related to the number 16 Sustainable development goal focused to public service institutions building and legal system which will allow stable environment released from corruption and violence, in which citizens could enjoy their own personal and political rights (Vlada Republike Srbije/Republički sekretarijat za javne politike, 2024, str. 47). In the previously mentioned national document from the page 47 to the page 54 there are listed numerous of formal and statistical data and documents related to the number 16 Sustainable development goal. Concretely what officials of Belgrade have adopted in the process of realization on the legislative level, what have been done on the statistical level from the institutional perspective and how much this political subject is engaged on international level in the process of contribution. But there is an evident discrepance between the mentioned document and European Commission Annual Report. There are no doubts that Belgrade have done a lot on legislative level, based on the data of the used national document. But there are also no doubts that Belgrade has done very little in practice, based on the data of the analyzed EU Report. Both documents serve as a basis for understanding the essence of the issue of small and weak states in the context of sustainable development and sustainability. Concretely, massive bureaucracy and legislative framework are creating picture of declarative functionality. However, the results of foreign policy activism and the risks, challenges and threats within the domestic institutional and political framework are testifying contradictory trend, respectively, that legislative preparedness is not followed by the executive effectiveness.

Skopje: In the context of Skopje, there is an online platform titled "National development strategy" in which the rule of law is placed through the prism "Governing in the citizens function". In the context of judiciary, this so-called strategic platform has put the focused to the following domestic challenges: disrupted trust in the judiciary and high dependence on the executive branch; shortage of staff in courts and public prosecutors' offices; insufficiently digitized, transparent and accountable judiciary; insufficiently inclusive and gender-balanced judiciary. In the range fighting corruption there are following challenges: insufficient fight against corruption (lack of capacity, finances for the Public Prosecutor's Office to prosecute organized crime and corruption and lack of focused policies to prevent corruption); inadequate system of sanctions for violations of rules for preventing corruption and conflict of interest and failure to implement confiscation of assets and seizure of objects originating from criminal acts or whose origin cannot be proven. In the context of public administration focus has been put to limited progress in public administration reform; weak models and weak approaches to governance; freedom of expression is making limited progress: problems in coordination at local/regional level and at national level; insufficient digitalization of public services (Национална развојна стратаегија, 2025). Quite similar assessment as those one in the European Commission Annual Report related to domestic institutional and political challenges, risks and threats. But there is a lack of strategic compass about the direction, as well as eligible instruments and mechanisms in the process of facing and managing listed domestic issues.

Podgorica: "National strategy for sustainable development to 2030" states that "good governance, as well as the effective fight against corruption and organized crime, remain challenges despite the efforts made in the previous period. In conditions of rapid changes in the legal framework and harmonization with the Acquis Communautaire, which entail a series of sensitive transformations, insufficient trust in the institutions of the system and the functioning of the rule of law prevents social cohesion, which is necessary for the

sustainability of the system. The perception that party structures influence the state apparatus further complicates the building of social consensus regarding strategic directions of development. From all of the above, the conclusion is that strengthening institutions, and thus trust in them, should be one of the basic strategic goals of sustainable development" (Crna Gora/Ministarstvo održivog razvoja i turizma, 2016, str. 53). This political entity, similar as in the case of Skopje, puts the focus on the serious institutional challenges which are additionally threatened by the current political framework. In comparison to Belgrade and Skopje, it is valuable to note that Podgorica in its national strategic document puts emphasis on the strengthening the institutions as a goal, placed on the level of strategic sustainable development goal.

Sarajevo: The SDGs framework in Bosnia and Herzegovina was adopted in December 2020(The SDGS framework in Bosnia and Herzegovina, 2020). In the referred strategic document Sarajevo officials have stated that efficient, open, inclusive and accountable public sector, plus rule of law, security and fundamental rights, plus resilience to disasters, could contribute to good governance and public sector management[1]. In the context of applicable measures in the document is mentioned "depoliticization and professionalization of the administration", as well as the "enhance fight against corruption, which remains to be one of the most serious problems in the country"(The SDGS framework in Bosnia and Herzegovina, 2020 str. 20 and 21). Analyzed document has also shown the institutional and political obstacles and barriers on the Sustainable Development path, as an important determinator of the whole process, but the document lacks to provide concrete measures in the form of steps which will lead to resolution of the domestic issues, thus fostering the path to the SDGs.

Pristina: In the context of the Pristina's "National Development Strategy (NDS) 2030" it is quite interesting to note that, as it is stated, "strategy aims to align with the EU accession agenda and integrated the Sustainable Development Goals (SDGs) into its objectives. Further, it is based on four key pillars "Rapid and sustainable economic development", "Human development", "Good governance", including the issue of "Security and rule of law" in which focuses are on "strengthening the rule of law, which is a critical component for the country's development and EU integration" (National Development Strategy and Plan 2030, 2023). In the context of goals, which is significantly important for this study, EU integration is placed as a first goal, stating that "the strategy is designed to help Kosovo meet the criteria for EU membership" (National Development Strategy and Plan 2030, 2023). Pristina's authorities have made direct linkage between foreign policy positioning and achieving the foreign policy goals and the sustainable development and sustainability as a final goal of each of the political entity. Thus, through the empirical example of the strategic document on the case of Pristina, authors have in practice proven the realistic relationship between the issue of sustainability and the foreign policy activism from the domestic (institutional) perspective, because in Pristina's strategy, in the field of "Key pillars of the NDS 2030", the issues of rule of law and security are directly positioned as a determinators of development and EU integration.

Tirana: In the case of Tirana, on strategic plan there is even clearer connection between sustainability from one side, and the foreign policy positioning, from another, taking into account the fact that the national document which deals with aforementioned segments is titled "National Strategy for Development and European Integration 2022-2030". In the content of the analyzing document of Albania, European integration is positioned as a primary goal which is followed by the needs such as reforming the justice system,

[1]In the referred strategic document Sarajevo officials have stated that efficient, open, inclusive and accountable public sector, plus rule of law, security and fundamental rights, plus resilience to disasters, could contribute to good governance and public sector management.

strengthening human rights, securing and protecting property rights, strengthening legislative and electoral processes, as well as foreign policy (National Strategy for Development and European Integration 2022-2030, 2023). Further, in the document it is clearly stated that "National Strategy for Development and European Integration 2030 is the main strategic document that gives directions and defines the priorities of the sustainable economic and social development of the country on the way to its full membership in the European Union, including the connection with the Sustainable Development Objectives in function of achieving the goals of the 2030 Agenda by defining the vision for the development of democracy, social and economic development of the country during the period 2021-2030" (National Strategy for Development and European Integration 2022-2030, 2023, str. 2). Tirana in comparison to other Western Balkans actors, has had even more explicitly pointed out the linkage between the foreign policy goals and SDGs, which additionally strengthens the authors thesis about the relationship between foreign policy effectiveness and sustainability issue on national level, precisely on the small and weak states case study.

Overal: Each of the six national documents or strategies related to sustainable development are directly or indirectly connected to European integration process, respectively to the foreign policy positioning. Authorities in Tirana and Pristina have even made concrete and precise linkage between the EU integration criteria and the reaching process of SDGs. In that context, authors have explained the rationale for paralel data analysis process of the EU Commission Annual Reports and SDGs national strategic documents of the case study entities. The linkage between the internal (institutional and political) preparedness and foreign policy activism is more than clear in practise. At the same time, the cause and effect relationship between foreign policy activism and its effectiveness from one side, and the issue of sustainability of another, is proven.

2.3. Gap in Knowledge: Identify gaps in the existing literature that the current study aims to address

Authors have used to opportunity to explain the connection between foreign policy positioning from one side and the issue of sustainability, from another, on the case of small states with limited material and qualitative capacities, but also weak states with limited institutional, political and personal strategic approach. The linkage between foreign policy positioning and the sustainability phenomena from one side explains the necessity of strong, reliable and persistent domestic institutional framework, as a basis for foreign policy success in the context of lack of material resources. From the other side, it explains the contribution of domestic institutional and political system in the process of defined foreign policy positioning, as an only and irreplaceable qualitative resource in the general process of securing sustainability. Authors research was not focused to identifying the gaps in the existing literature, bearing in mind the spectrum of different foreign policy approaches and explanations about the small states, but to provide contribution in the future scientific research, putting emphasis on the correlation between foreign policy activism and sustainability issues, as a "door" for further debates. From the other side, to provide clearer picture about the distinction between the small states from one side, and those one small but institutionally weak, from another, using the institutional and political framework as a qualitative resource, thus variable in the foreign policy positioning and securing sustainability.

3. Discussion

Authors have based the discussion on theoretical grounds, bearing in mind the internal challenges, risks and threats that small and weak states are facing, such as the empirical example political entities in this study. Through the prism of neoclassical realism, thus

through the neoclassical realism explanation about the influence domestic/internal flows in understanding the foreign policy positioning of certain subject in international system, authors will deepen the discussion on two linked levels: the foreign policy effective positioning, from one side, and sustainability, from another. Miriam Fendius Elman believes that small states foreign policy provides a unique opportunity for those scholars who insist that domestic politics matters in explaining international and foreign-policy outcomes. Further, he says that "weak state foreign policy presents crucial test for domestic level theory" (Elman, 1995, str. 172). But he also emphases that "the received wisdom in the field is that domestic determinants will be less salient when studying small state behavior because external constraints are more severe and the international situation is more compelling" (Elman, 1995, str. 172). However, Steinsson (2017) and Wivel (2013) rely on neoclassical realist approaches to show that domestic politics is still an important element in the foreign policies of small states (Thorhalsson, 2018, str. 24). Thorhallsson explains that "neoclassical realism posits that states seek to defend their long-term security interests but that the pursuit of security interests will be distorted in the short-term by miscalculations by leaders and domestic politics" (Thorhalsson, 2018, str. 24). Oppositely to neoclassical realists, but in line with Miriam Fendius Elman positions, Michael Handel declares that "domestic determinants of foreign policy are less salient in weak states, so the international system leaves them less room for choice in the decision-making process" (Handel, 2006, str. 149). But, in the context of presented data analysis of the empirical examples, concretely through the prism of foreign policy strategic goals of Western Balkans actors from one side, and EU Commission Annual Reports, from another, there is an explicit linkage between foreign policy positioning of small states and their domestic/internal (institutional and political) flows. We could refer that the Miriam Fendius Elman and Michael Handel positions are correct if we analyze from the perspective of EU membership criteria. In that context foreign policy positioning of Western Balkans actors depends of fulfilling the "internationally" (European) imposed preconditions. But, if we analyze the foreign policy positioning from the perspective of the internally placed strategic foreign policy goals of Western Balkans actors, defined on the national interest's basis and agreed on the political and social level, then we could not claim that foreign policy positioning of small and weak states is exclusively dependent of international flows. There is the rationale in the explanation given by Miriam Fendius Elman and Michael Handel and the purpose of this study is not to deny in its entirety. But, to provide wider explanation in which also finds the applicability of neoclassical realism approach about the domestic/internal determinants in the foreign policy positioning, using the negative example of Western Balkans actors. By proving the linkage between foreign policy positioning and the issue of sustainability on the pragmatical example of Western Balkans actors, through the data analysis of EU Commission Annual Reports and national documents related to SDGs, authors have confirmed the thesis that the constant of foreign policy strategies of small and weak states is the issue of existence, in this study through the concept of sustainability. From the other side, authors have fostered the already ongoing debate between IR scholars about the determinants of foreign policy behavior of small and weak states, thus once again opening the prism of internal factors in the process of realization of foreign policy goals. Concretely, this study contributes in horizontal and vertical in the future research activities within the IR scholar's framework, thus deepening the debate about the foreign policy capacities of small states and creating basis for analysis the effectiveness of foreign policy positioning through the SDGs prism.

4. Conclusion

The article has justified its purpose through proving and explanation the relationship between internal (domestic) institutional effectiveness, foreign policy activism and realization of foreign policy goals and the sustainable development goals and sustainability from the perspective of national interests. On the case study of small and weak states authors have explained the challenges, risks and threats that the process of realization of SGDs bring to the states which are placed as empirical examples in the context of their overall sustainability.In that context, authors have made a contribution in the understanding of small and weak states in the current chapter of international relations from the perspective of their positioning, thus providing an explanation on the question what determines their foreign policy positioning.On the other hand, authors have deepened the theoretical debate on the foreign policy' positioning between subjects of international system, thus challenges traditional concepts and giving a relevance to internal (domestic) variables in the foreign policy activism.

In fact, this study provides threefold contribution: understanding about the issue of sustainability and the national interests, thus explaining the sustainability is not a new concept, but issue extremely linked to the preservation of national interests; about the variables of foreign policy effectiveness of small states with the focus on internal (domestic) variables; about the personal (political) dimension in the decision-making process in the field of foreign policy versus institutional infrastructure and the consequences of the "party" or political patronage above institutional system.

Finally, this study provides an alternative perspective about the small states in contemporary international relations which is not based exclusively on the quantitative and material resources, but on the qualitative mechanisms and skills which could be understand through the SDGs perspective. Thus this study opens further theoretical debate, especially in the context of small and weak states, looking for the comprehensive explanation how to release captured institutional framework from the political and personal decision-making process, thus making it able to serve to SDGs, which is, literally, to the process of preserving national interests.

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CURRENT QUALITY OF CROSSREF METADATA IN MACEDONIAN SCIENTIFIC JOURNALS (2025)

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ABSTRACT

Introduction: *When a publisher registers a DOI with Crossref, they are also expected to submit associated metadata—structured information about the content, such as the title, authors, publication date, abstract, funding data, references, ORCID iDs, and more. We aimed to analyse the current quality of Crossref Metadata in Macedonian scientific journals, and to suggest mechanisms for increase of the Crossref metadata quality in Macedonian scientific journals.*
Methods: *On February 15, 2025, an analysis was conducted using Crossref's "Participation Reports – How good is your metadata?" tool (https://www.crossref.org/members/prep/) to identify publishers from the Republic of North Macedonia depositing Crossref metadata. The analysis, which focused exclusively on journal articles using the "All time" option (excluding books, book chapters, proceedings, and conference papers), revealed a total of 37 publishers and one co-publisher—Sciendo, De Gruyter Poland Sp. z o.o., based in Warsaw, Poland. Altogether, 37,595 registered content items from these Macedonian publishers were included in the evaluation.*
Results: *The 2025 analysis of Crossref metadata in Macedonian scientific journals shows limited participation, with only 37 out of around 140 publishers represented. DOI deposits are led by a few key institutions, but reference, ORCID iD, affiliation, funding, and Crossmark metadata are largely missing, especially from major public universities. Abstracts are more widely deposited, though inconsistently across institutions. Text mining, license URLs, and similarity checks are poorly implemented, and no publishers have submitted ROR identifiers. Only three journals published via De Gruyter demonstrate strong metadata quality in several areas, but still lack key elements like ORCID, ROR, and funding data.*
Discussion: *Current Crossref metadata quality in Macedonian scientific journals (2025) is very low. Only smaller part of Macedonian scientific journals uses DOI numbers. Most of the*

Macedonian scientific journals do not deposit Crossref metadata services (Metadata Retrieval, Content Registration, Reference linking, Cited-by, Funder Registry, Similarity Check, Crossmark).

Keywords: Crossref metadata; scientific journals; Macedonia

INTRODUCTION

Crossref plays a fundamental role in scholarly communication by acting as the principal registry for Digital Object Identifiers (DOIs) and their associated metadata (Van Eck and Waltman 2022). Its infrastructure supports discovery, citation linking, and interoperability across research systems. However, the quality of metadata submitted to Crossref varies significantly, raising concerns about discoverability, the accuracy of citation networks, and the integrity of bibliometric analyses.

Many academic publishers collaborate with Crossref to registerDOIs for their outputs, and in doing so, they can deposit bibliographic metadata associated with those publications. Crossref makes this metadata openly accessible to the public. Through the large-scale availability of such open bibliographic metadata, Crossref has emerged as an increasingly valuable resource for bibliometric research(Hendricks et al. 2020). Open Crossref metadata supports more transparent, reproducible, and inclusive bibliometric analyses(Hendricks et al. 2021) and enables novel methods for discovering scholarly literature, as well as more responsibleuseof bibliometric indicators in research evaluation. Furthermore, metadata provided by Crossref underpins major downstream data infrastructures, including OpenAlex (Priem et al. 2022) and Dimensions (Hook et al. 2018).

One prominent issue is the phenomenon of "sneaked references," in which citations are registered in Crossref metadata but do not actually appear in the published article's reference list. Such manipulations can inflate citation counts and propagate through bibliometric platforms (Besançon et al. 2023). More recent work has confirmed that such manipulations persist at scale: for example, Besançon et al. (2025) detected over 80,000 sneaked references in metadata for a single journal, revealing systemic vulnerabilities in Crossref's reliance on publisher-supplied citation data.

Given the scale and importance of Crossref, evaluating its metadata quality is critical. Poor-quality metadata can propagate errors across citation indexes, distort bibliometric measures, and undermineresearch discovery. Accordingly, this analysis aims to assess the current state of Crossref metadata along several dimensions — including completeness, accuracy, risk of manipulation, and multilingual consistency — in order to identify persistent weaknesses and propose actionable improvements.

We aimed to analyse the current quality of Crossref Metadata in Macedonian scientific journals, and to suggest mechanisms for increase of the Crossref metadata quality in Macedonian scientific journals.

Methods

Identification of publishers from Macedonia which deposit Crossref metadata = 37 publishers and 1 co-publisher (Sciendo, De Gruyter Poland Sp. z o.o., Bogumila Zuga 32a, 01-811 Warsaw, Poland) were included in the study. Macedonian publishers were analysed on February 15, 2025, with the Crossref tool, Participation Reports, How good is your metadata? (https://www.crossref.org/members/prep/).

The option "All time" was used for publisher analysis of journal articles. Books, book chapters, proceeding, and conference papers were not included in this presentation. Total number of 37 595 registered content items were analysed for each publisher from RN Macedonia.

Results

At the moment, there are 12 members of Crossref from RN Macedonia, mainly from governmental institutions (Ss. Cyril and Methodius University in Skopje, Faculty of Economics – Skopje; University of Tetovo; European Scientific Institute, ESI; International Balkan University; Macedonian Academy of Sciences and Arts; and University St. Kliment Ohridski – Bitola) and societies (Macedonian Pharmaceutical Association; Albanians' Stomatological Society; Union of Researchers of Macedonia; Society of Chemists and Technologists of Macedonia; Association-Institute for English Language and American Studies, Tetovo; and Balkan Studies Foundation). The number of scientific journals is bigger than 12, because there are similar DOIs with different suffixes (Table 1).

Table 1. Members of Crossref from RN Macedonia (n = 12).

Name of the Crossref member	DOI prefix
Ss. Cyril and Methodius University in Skopje, Faculty of Economics - Skopje	10.47063
Macedonian Pharmaceutical Association	10.3332
Albanians' Stomatological Society	10.62636
Union of Researchers of Macedonia	10.37418
Society of Chemists and Technologists of Macedonia	10.2045
Association-Institute for English Language and American Studies, Tetovo	10.58885
University of Tetovo	10.62792
European Scientific Institute, ESI	10.19044
Balkan Studies Foundation	10.51331
International Balkan University	10.69648
Macedonian Academy of Sciences and Arts	10.20903
University St. Kliment Ohridski – Bitola	10.20544
TOTAL	**12**

The biggest number of DOIs are sponsored by National and University Library – St Kliment of Ohrid – Skopje (18), followed by Scientific Foundation SPIROSKI (3), and the rest of DOIs are sponsored by Albanian Canadian Development Alternative (1), Institute of Knowledge Management (1), ASOS Publishing (1), and Han Yazilim Bilisim Hilzetmleri (1), or in total 25 DOIs from RN Macedonia are sponsored. The number of scientific journals is bigger than 25, because there are similar DOIs with different suffixes (Figure 1).

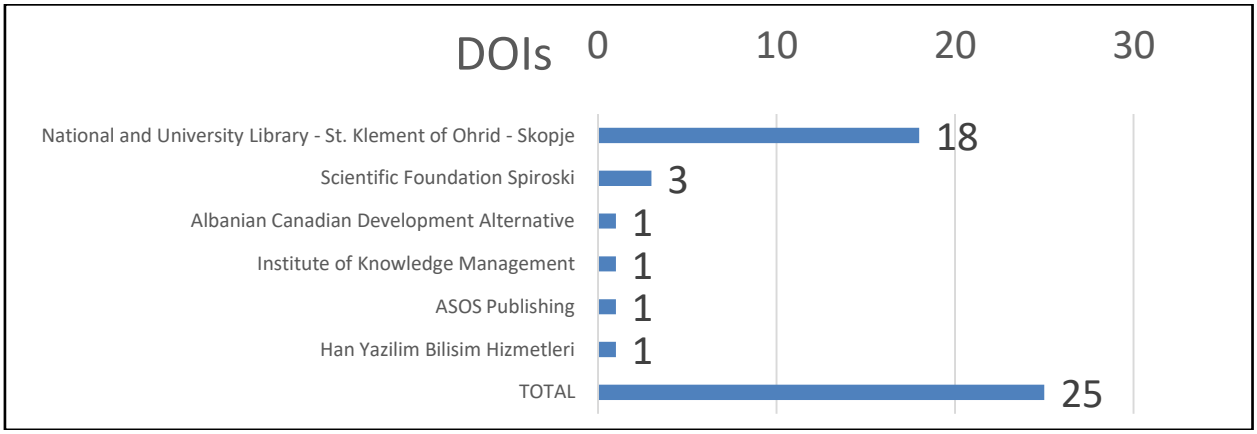

Figure 1: Sponsor organisations for DOIs in RN Macedonia

The current quality of Crossref metadata in Macedonian Scientific Journals (2025) is shown in Table 2.

DOI Deposits - The highest number of DOIs was deposited by: (1) InTouch Publishing; (2) European Scientific Institute; (3) Scientific Foundation Spiroski; and (4) Ss. Cyril and Methodius University in Skopje. Despite the number of active scientific journals in Macedonia being around 140, only 37 publishers are represented in Crossref, indicating that DOI assignment remains limited (Table 2).

Reference Metadata - Only 7 publishers have deposited references in Crossref metadata. The top contributors are: (1) Macedonian Pharmaceutical Association; (2) Scientific Foundation Spiroski; and (3) Journal of Special Education and Rehabilitation. Notably, several major universities, such as Ss. Cyril and Methodius University in Skopje, St. Clement of Ohrid University of Bitola, and the University of Tetovo, have not deposited reference metadata (Table 2).

Abstract Metadata - More than half of the publishers have deposited abstracts in Crossref. However, governmental Universities perform poorly: University of Tetovo: 100% abstract deposition; Goce Delchev University in Shtip: 0%; and Ss. Cyril and Methodius University in Skopje: 2% (Table 2).

ORCID iDs - The highest number of deposited ORCID iDs came from: Association for Educational Development "To Future"; International Balkan University; and Scientific Foundation Spiroski. Major Governmental Universities have not deposited ORCID iDs (Table 2).

Affiliation Metadata - The Macedonian Pharmaceutical Association leads in affiliation metadata deposition. Most others are underrepresented or missing completely (Table 2).

Research Organization Registry (ROR) - No Macedonian publisher has deposited ROR identifiers (Table 2).

Funding Registry and Award Numbers - Only Scientific Foundation Spiroski has deposited a small percentage of funding information and award numbers. All others have submitted none (Table 2).

Crossmark Metadata - Only two organizations included Crossmark metadata: Institute of Knowledge Management; and European Scientific Institute (Table 2).

Text Mining and License URLs - Text mining metadata is poorly deposited. Two-thirds of journals have no text mining entries. License metadata is similarly incomplete, with better results only from a few institutions such as: Society of Science and Technology of

Macedonia; Scientific Foundation Spiroski; Macedonian Academy of Sciences and Arts; and American Studies in Tetovo (Table 2).

License URLs - Universities like Ss. Cyril and Methodius, St. Clement of Ohrid, and University of Tetovo did not deposit license metadata (Table 2).

Similarity Check - Only one-third of the analyzed content includes similarity check metadata (Table 2).

Table 2. Current Quality of Crossref Metadata in Macedonian Scientific Journals (2025).

Name (15.02.2025)	Total registered content items (all time)	References (%)	Abstracts (%)	ORCID iDs (%)	Affiliations (%)	ROR IDs (%)	Funder Registry IDs (%)	Funding award numbers (%)	Crossmark enabled (%)	Text mining URLs (%)	License URLs (%)	Similarity Check URLs (%)
University St. Kliment Ohridski Bitola - Scientific Tobacco Institute	0	0	0	0	0	0	0	0	0	0	0	0
University St. Kliment Ohridski - Bitola	460	2	11	0	2	0	0	0	0	0	0	0
University Ss. Cyril and Methodius in Skopje	2 375	0	2	0	0	0	0	0	0	0	0	0
University of Tetovo	361	0	100	0	0	0	0	0	0	0	0	0
Union of Researchers of Macedonia	1 627	0	27	0	3	0	0	0	0	0	0	99
TEMEL Citizens' Association Center for Development, Organization, Research, Promotion of Values, Education and Promotion of Youth, Bitola	47	0	0	0	0	0	0	0	0	0	0	0
Ss. Cyril and Methodius University in Skopje, Faculty of Economics – Skopje	176	0	95	5	5	0	0	0	0	0	5	95
Society of Chemists and Technologists of Macedonia	420	0	94	14	0	0	0	0	0	94	95	94
Scientific Foundation Spiroski	6 654	58	93	28	0	0	3	2	0	92	91	95
Qendra për marrëdhënie ndërkombëtare e studime ballkanike	68	27	91	5	0	0	0	0	0	95	25	95
Public Scientific Institution Institute of Old Slavic Culture - Prilep	130	0	0	0	0	0	0	0	0	0	0	0
Matematichki Bilten, Union of Mathematicians of Macedonia	159	0	0	0	0	0	0	0	0	0	0	0
Macedonian Pharmaceutical Association	897	97	24	0	86	0	0	0	0	0	0	99
Macedonian Marketing Association Marketing – Skopje	0	0	0	0	0	0	0	0	0	0	0	0
Macedonian Geographical Society	70	0	0	0	0	0	0	0	0	0	0	0
Macedonian Ecological Society	98	0	0	0	0	0	0	0	0	0	0	0
Macedonian Archaeological Society	0	0	0	0	0	0	0	0	0	0	0	0
Macedonian Academy of Sciences and Arts	175	0	98	0	0	0	0	0	0	99	100	99
Macedonain Heraldic Society	85	0	0	0	0	0	0	0	0	0	0	0
Journal of Special Education and Rehabilitation	116	30	12	0	0	0	0	0	0	0	0	24
Journal of Liberty and International Affairs, Institute for Research and European Studies – Bitola	287	0	0	0	0	0	0	0	0	0	0	0
International Vision University	110	0	0	0	0	0	0	0	0	0	0	0
International Balkan University	70	0	92	44	0	0	0	0	0	0	0	0
Integrated Business Faculty	15	0	0	0	0	0	0	0	0	0	0	0
İntaç Eğitim Danışmanlık Organizasyon Araştırma İnşaat Sanayi ve Ticaret Limited Şirketi	12 177	0	8	8	8	0	0	0	0	0	0	0
Institute of Knowledge Management	1 755	14	100	0	1	0	0	0	4	80	13	84

Goce Delchev University – Shtip	799	0	0	0	0	0	0	0	0	0	0	0
Geobalcanica Society	116	0	0	0	0	0	0	0	0	0	0	0
Federation of Sport Pedagogues of Republic of Macedonia	40	0	0	0	0	0	0	0	0	0	0	0
Faculty of Tourism and Hospitality, Ohrid	0	0	0	0	0	0	0	0	0	0	0	0
Faculty of Philosophy, Skopje	555	0	0	0	0	0	0	0	0	0	0	0
European Scientific Institute, ESI	7 292	0	78	0	0	0	0	0	1	70	23	70
DOOEL OTA PUBLICIRANJE s.Lavci Bitola	16	0	0	0	0	0	0	0	0	0	0	0
Association-Institute for English Language and American Studies, Tetovo	305	8	100	13	0	0	0	0	0	99	75	99
Association of Practitioners of TCM Tong Da Tang TCM, Skopje	49	0	0	0	0	0	0	0	0	0	0	0
Association of Education and Thought Fettah Efendi	77	0	75	97	0	0	0	0	0	0	0	0
Albanians' Stomatological Society	14	0	100	0	0	0	0	0	0	0	0	0
TOTAL	37 595											

Exception (Journals via De Gruyter) - Three journals (Balkan Journal of Medical Genetics, Macedonian Veterinary Review, and PRILOZI) have deposited data through Walter de Gruyter. These journals show very good to excellent metadata quality for references, abstracts, affiliations, text mining, licenses, and similarity check, but lack ORCID iDs, ROR, funding, and Crossmark metadata (Figure 2).

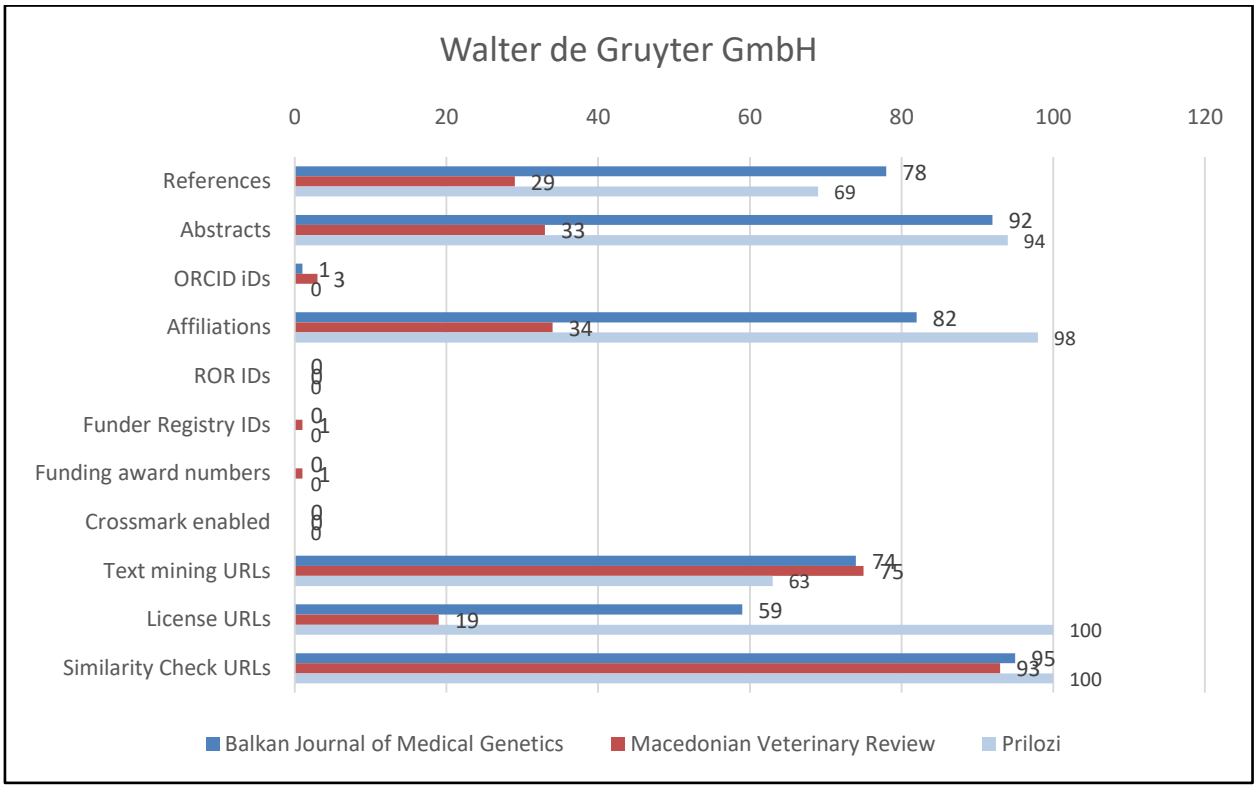

Figure 2: Crossref Metadata of Macedonian Journals co-published with Walter de Gruyter GmbH (results in % of deposited DOIs)

One successful case involved a journal formerly hosted on www.heraldika.org.mk. The editor-in-chief decided to upgrade the journal and partnered with Scientific Foundation Spiroski to improve the metadata. Initially, on February 15, 2025, the journal had zero metadata quality across all 11 items. One month after corrections and resubmission, the metadata quality significantly improved - demonstrating that progress is possible with active collaboration (Figure 3).

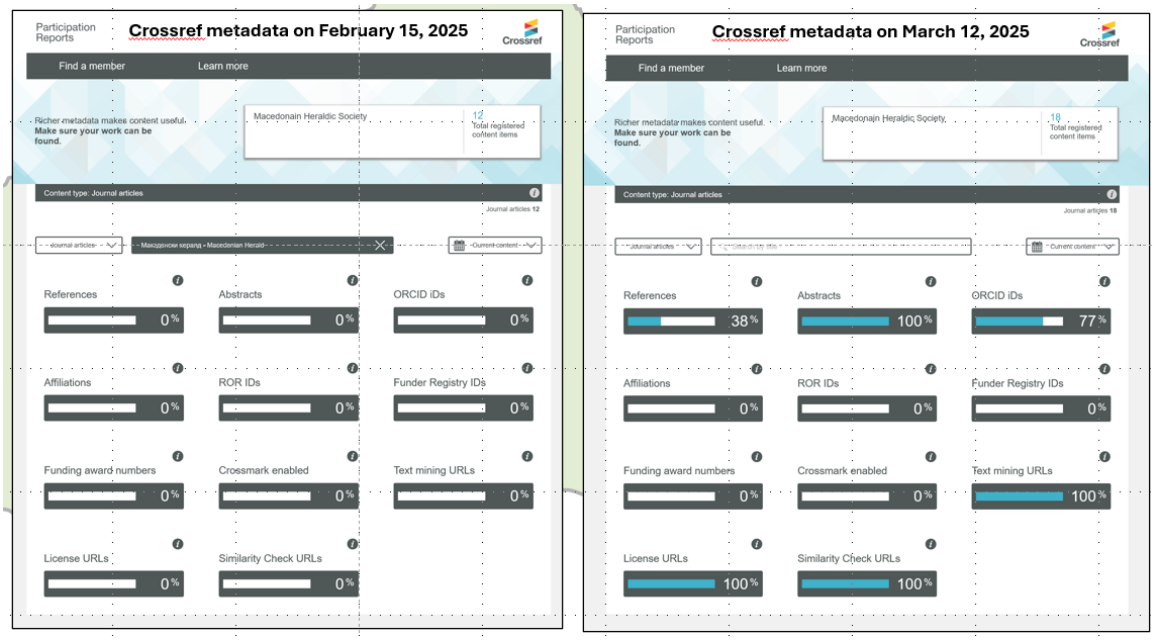

Figure 3: Macedonian Heraldic Society moved the content of Macedonian Herald journal to https://journals.mk/index.php/mkherald. We updated URLs and metadata. The results are shown before (left February 15, 2025) and after update (right March 12, 2025) to increase the quality of metadata

DISCUSSION

In this paper, we present the results from the current analysis of Crossref metadata in Macedonian scientific journals (2025). Our assessment reveals several significant gaps in metadata practices. Although Macedonia hosts approximately 140 active scientific journals, only 37 publishers are represented in Crossref, with the most DOI deposits coming from InTouch Publishing, the European Scientific Institute, Scientific Foundation Spiroski, and Ss. Cyril and Methodius University in Skopje. However, reference metadata is deposited by only seven publishers, led by the Macedonian Pharmaceutical Association and Scientific Foundation Spiroski. Major academic institutions, including Ss. Cyril and Methodius University and University of Tetovo, have not deposited reference metadata at all. Abstract metadata coverage is inconsistent: while University of Tetovo achieves full(100%) deposition, other universities such as Goce Delchev and Ss. Cyril and Methodius, report extremely low rates.

Additional gaps are evident in the deposition of ORCID iDs, affiliation data, and other advanced metadata elements. ORCID iDs are primarily submitted by smaller institutions, such as the Association for Educational Development "To Future" and the International Balkan University, while government-funded universities remain largely inactive. Only the Macedonian Pharmaceutical Association shows substantial affiliation metadata, and no publishers have deposited Research Organization Registry (ROR) identifiers. Funding information and award numbers are almost entirely absent, with minimal contributions from Scientific Foundation Spiroski. Similarly, Crossmark metadata is deposited by just two publishers, and text mining and license metadata remain highly incomplete. Universities such as Ss. Cyril and Methodius, St. Clement of Ohrid, and Tetovo failed to provide license URLs. Overall, only one-third of journals include similarity check metadata, underscoring the widespread need for improved metadata practices across Macedonian scholarly publishing.

To improve metadata quality in Macedonian scientific journals, we must take action. Crossref provided data indicating that 12 Macedonian publishers are full members of Crossref. They are independently responsible for their metadata quality. Additionally, some organizations act as sponsors for Crossref in Macedonia: Institute of Knowledge Management; National and University Library "St. Clement of Ohrid"; and Scientific Foundation Spiroski. As sponsors of Crossref, they are expected to support metadata quality improvement among their members (National and University Library: 18 DOIs; Scientific Foundation Spiroski: 3 DOIs; Other sponsors (e.g., Acco Publishing, Turkish-based Yazim Bilisim Hizmetleri): 1 DOI each). Scientific foundation Spiroski was included as a sponsor of Crossref in January of 2025, and they are committed to support all Crossref services (including DOI assignment; metadata retrieval; content registration; reference linking; cited-by; ror; similarity check; and crossmark), as well as training and educational resources such as webinars, instructional videos, and website materials (https://www.journals.mk/index.php/index/crossref).

There are several key moments when it is especially valuable for journals to audit or update their metadata: a) when URLs change; b) when switching publishing platforms; and c) when a journal is transferred to another publisher. Additionally, if a journal begins collecting new types of metadata—such as funding information—those records should be updated accordingly. Ideally, journals should also set a regular schedule to review and audit their metadata in line with any changes in internal policy. This ensures the records remain accurate and complete.

If metadata such as author affiliations are missing—as is the case with many Macedonian journals—then institutions cannot be accurately linked to their research output. A past study on AI in Macedonian publications showed that over 2.07K papers lacked proper affiliation metadata and were only attributed to "Republic of Macedonia" (Spiroski and Spiroski, 2025).

The Crossref Participation Reports tool can help identify the most essential metadata elements. While Crossref allows for a wide range of metadata types, journals with limited resources can focus on the 11 key metadata elements that significantly enhance content discoverability. Prioritizing quality over quantity is crucial. Accurate, well-maintained metadata—even if limited in scope—is far more valuable than having numerous but inaccurate records. Regularly auditing and improving just these 11 elements can greatly improve visibility and compliance. Many research organizations in Macedonia are not registered in the Research Organization Registry (ROR), making it impossible to link them accurately. For improved metadata to truly support collaborations and visibility, a national effort is required to ensure institutions, authors (via ORCID), and papers (via DOI) are properly registered and linked.

We discovered a general lack of understanding of how to properly submit or maintain metadata. Until now, most scientific journals in Macedonia have only deposited DOIs and landing pages—without additional, valuable metadata. This is not about blaming any institution; it reflects a widespread unpreparedness to meet modern scientific publishing standards. Of the six sponsors linked with Macedonian metadata, three are foreign institutions. Interestingly, these foreign sponsors tend to have higher metadata quality, highlighting the need to improve domestic capacity. Historically, depositing DOIs was seen as sufficient. However, to truly benefit from metadata, all 11 key elements should be included. Full Crossref members are responsible for ensuring that their metadata goes beyond just DOIs.

In the published paper about Identifying Metadata Quality Issues AcrossCultures, authors concluded (Shi et al. 2025) that metadata records should be treated as sites in need

ofcritical, intellectual engagement to surface the perspectives and identities embedded and obscuredin their creation. In taking up the responsibility of describing a researcher's output ina record, journal editors and publishers also have a responsibility to the researcher to ensurethat their contributions and identity are represented as fully as relevant and possible to theirwork and the communities most affected by it.

There is an interesting notification where Ansorge 2023 compared the citation frequencies ofarticles published in *European Science Editing*using the Dimensions and Scopus databasesand concluded, "Data on citations in theDimensions database could be more accurateif the references appended to the citing articleslisted in the Crossref database were underan open license." He cocluded that this issue arises when thepublishing company neglects to include referenceswhen depositing the DOI to Crossref.

While some may consider changing sponsors as one possible path forward, the core issue is education. Universities must understand that metadata completeness is crucial. Whether or not journals choose to work with sponsors or independently, what matters most is recognizing the need for complete, high-quality metadata.

CONCLUSIONS

Crossref metadata quality in Macedonian scientific journals is very low. Only smaller part of Macedonian scientific journals uses DOI numbers. Most of the Macedonian scientific journals do not deposit Crossref metadata services (Metadata Retrieval, Content Registration, Reference linking, Cited-by, Funder Registry, Similarity Check, Crossmark). Macedonian scientific journals should increase Crossref metadata services by resubmission of corrected metadata and provide more complete metadata services free of charge.

Crossref Macedonia is prepared to accept current Macedonian scientific publishers for resubmission of corrected metadata services and to enable more precise future depositions.

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INTERGOVERNMENTAL COORDINATION AND REINTEGRATION STRATEGIES IN NORTH MACEDONIA'S FIGHT AGAINST VIOLENT EXTREMISM

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ABSTRACT

Introduction: *Current security challenges within the broader geopolitical context are significantly impacting North Macedonia. The objective of this study is to examine North Macedonia's strategies in countering violent extremism (CVE), addressing the reintegration of returnees, and improving intergovernmental coordination.*
Methods: *The research employs a qualitative approach, drawing on official reports, government documents, policy frameworks, and secondary academic sources related to North Macedonia's counter-terrorism and CVE efforts.*
Results: *Findings indicate that North Macedonia has established a reintegration strategy for approximately 40 of its citizens affiliated with the Islamic State. Around 50 individuals have been convicted of terrorism-related crimes. However, challenges persist, including lenient sentencing, limited reintegration outcomes, and weak interinstitutional coordination.*
Discussion: *While North Macedonia has introduced legal and financial measures to monitor returnees and initiated collaborative reintegration programs, these efforts remain fragmented. Overlapping competences among institutions continue to obstruct efficiency. A proactive, well-coordinated approach is essential for strengthening resilience against extremism.*

Keywords: North Macedonia, violent extremism, counter-terrorism, reintegration, Western Balkans

1. Introduction

Since 2012, North Macedonia has faced persistent challenges related to violent extremism and foreign terrorist fighters (FTFs). A total of 143 Macedonian nationals (133 men and 10 women), excluding children, were documented to have travelled or attempted to travel to conflict zones in Syria and Iraq. Of these, 69 individuals have returned, 38 were killed, and four remain in displaced persons camps in northeastern Syria. By the end of 2023, the

country had repatriated 30 nationals. While state authorities currently assess the terrorist threat level as "medium," influenced by global geopolitical tensions such as the war in Ukraine and recent Middle East conflicts, no new departures have been recorded since 2021. Arguably, this trend of decrease is a result of advanced legislation, enhanced security enforcement, and international cooperation. Nevertheless, despite notable progress, North Macedonia continues to face significant challenges in effectively coordinating and implementing policies on the rehabilitation, resocialization, and reintegration (RRR) of returned foreign terrorist fighters (RFTFs) and their families. This is predominantly due to the fragmentation of competencies among various institutions, limited specialized capacities, and insufficient support mechanisms for individuals at risk of radicalization. The abovementioned issues remain critical weaknesses that threaten long-term human security and social cohesion.

The issue of foreign terrorist fighters (FTFs) directly intersects with both human security and sustainable development, especially within the framework of the UN 2030 Agenda (A/RES/70/1). Terrorism and violent extremism undermine social stability, community trust, and economic development—conditions essential to achieving the Sustainable Development Goals (SDGs). North Macedonia's policies related to the FTFs contribute to several SDGs. Namely the undertaken steps related to FTFs and related RRR processes are in line with SDG 16 (peace, justice, and strong institutions) since are aimed towards prevention of radicalization and protection of communities; SDG 4 and SDG 8 are addressed by initiatives that supports education and awareness rising, as well as the providing employability of returned FTFs as part of their RRR processes; SDG 10 relates with efforts to tackle the inequality since they prove to be a catalysts for seeding extremist narratives in the society; and SDG 5 by addressing gender-specific vulnerabilities of women and children associated with FTFs. In general, it is accepted that addressing FTFs' issues requires a holistic approach that should strengthen community resilience, reduce security threats, and promote long-term social inclusion. However, the full success of these efforts depends on certain preconditions, such clear division of the institutional competences and mandates, strengthened operational coordination - at the national and local level, and sustained support for rehabilitation programs not only within prisons, but as well within communities where those convicts return. Therefore, a comprehensive "whole-of-society approach" remains essential to prevent recidivism and future radicalization in society. By assessing current frameworks and identifying critical shortcomings, this research supports policy improvements that will enhance human security, foster sustainable development, and reduce the long-term risks posed by terrorism and violent extremism in North Macedonia.

The objective of this study is to provide an analysis on the existing legal and institutional frameworks, as well as intergovernmental coordination mechanisms, that govern North Macedonia's efforts to address RFTFs — both imprisoned ones, as well as the ones that have completed their sentences. It is relevant since it addresses the topic that is not much researched in the Macedonian context, but it is crucial in reaching human security. The study assembles the knowledge gained through various research projects and initiatives that assess the national measures of the fight against terrorism. Additionally, it relates these efforts to good governance principles, international human rights standards, and sustainable development priorities. Moreover, it points towards gaps in undertaken measures and applied strategies, and provides actionable recommendations for more effective practice.

2. Literature review

The "Foreign Terrorist Fighters" or "violent extremism and radicalization that lead to terrorism" are concepts that remain challenging to define, due to varying scientific approaches and the political connotations embedded in their origins. The closest that definition can be "*Foreign terrorist fighters are individuals who travel to a State other than their States of residence or nationality for the purpose of the perpetration, planning, or preparation of, or participation in, terrorist acts or the providing or receiving of terrorist training, including in connection with armed conflict*" (UNSC Res. 2178/2014). Whereas the "*Violent extremism and radicalization that lead to terrorism is a dynamic process whereby an individual comes to accept terrorist violence as a possible, perhaps even legitimate, course of action. This may eventually, but not necessarily, lead this person to advocate, act in support of, or engage in terrorism*" (OSCE, 2019).

Due to the complexity of the phenomenon of "terrorism", the criminal codes of many countries, as well as the international conventions for the prevention and suppression of terrorism, do not establish a precise definition for the act. However, all actions labelled under the term ”terrorism” include an element of violence directed at people and property, but also an intention to endanger life and body and to create a sense of insecurity and fear among citizens. Therefore, the two elements that constitute the legal nature of act of terrorism are formulated objectively –as the commission of a serious act against life or a body, destruction of property, endangerment of the environment or other serious acts of violence or generally dangerous actions; and subjectively - the intention to endanger and create a feeling of insecurity or fear among an unspecified circle of peoples (Kambovski 2015).

2.1. International and regional instruments for FTFs

The gravity of the FTF phenomenon was reaffirmed by the United Nations Security Council (UNSC), with adoption of the Resolution 1373 (2001), and Resolutions 2178 (2014) and 2396 (2017). Resolution 1373 was adopted in the immediate aftermath of the September 11 attacks in the United States, introducing legally binding measures that required member states to take comprehensive actions to counter, prevent, and combat terrorism. A key aspect of this resolution was the obligation to criminalize not only terrorist acts themselves but also preparatory activities such as financing, planning, and providing support for terrorism. UNSC Resolution 2178 (2014) mandated that states take action to prevent, disrupt, prosecute, rehabilitate, and reintegrate FTFs. Additionally, it encouraged member states to collaborate with local communities and non-governmental actors in developing strategies to counter violent extremist narratives that may incite acts of terrorism. Resolution 2170 (2014) and Resolution 2178 (2014) were both adopted under Chapter VII of the UN Charter, which recognized the movement of FTFs as an international threat to peace and security. The resolutions mandate the development and implementation of administrative measures to prevent and combat the travel of FTFs. These measures include collecting biometric data, conducting data analysis, and sharing travel booking information with relevant state authorities (UNODC 2017). Furthermore, UNSC Resolution 2396 (2017) reinforced the commitments outlined in the 2014 resolutions, urging member states to cooperate and support each other’s efforts in addressing FTFs. It also called on all states to establish serious criminal offenses related to the travel, recruitment, and financing of FTFs, as well as to take appropriate measures concerning suspected terrorists and their accompanying family members. These measures include prosecution, rehabilitation, and reintegration, all in accordance with domestic and international law.

Considering the regional practices, the Council of Europe has established a key legal framework to prevent and counter terrorism. The most significant one is the Convention on the Prevention of Terrorism 196 that entered into force in 2007. Rather than introducing new definitions of terrorism, the Convention builds on existing anti-terrorism conventions by defining additional offenses that could lead to acts of terrorism. These newly defined offenses include "public provocation to commit a terrorist crime," "recruitment for terrorism," and "training for terrorism", as well as related offenses that criminalize complicity in such acts. Additionally, attempts to commit these crimes are also criminalized (Articles 5-9). Notably, the Convention states that an indictment under its provisions does not require the actual commission of a terrorist act. This principle is explicitly stated in the Convention and is based on a similar provision in the International Convention for the Suppression of the Financing of Terrorism, where the location in which offense occurs is not a determining factor in prosecuting any of the crimes outlined in the Convention, The Additional Protocol to the Council of Europe Convention on the Prevention of Terrorism (2015), CETS No. 217 was introduced to address the criminal-legal aspects of the FTF and returnee phenomenon. The Protocol entered into force in 2017 and requires signatory states to criminalize specific acts, including participation in a terrorist organization, terrorist training, traveling abroad for terrorist purposes, and financing or organizing such travel (Articles 2-6).

The Republic of North Macedonia is a signatory and has ratified all of the above-mentioned instruments.

2.2. National legal frame

North Macedonia's legislative framework is broadly aligned with the *EU acquis* and international counterterrorism instruments (European Commission, 2024). National legal framework for the incrimination of terrorist acts and the activities of FTFs is outlined in the Criminal Code, the Law on Prevention of Money Laundering and Financing of Terrorism, and the Law on Execution of Sanctions.

The Criminal Code (CC) (1996) contains multiple provisions that regulate illegal conduct associated with executing, inciting, assisting, or financing acts of terrorism. Like the other examples, the Macedonian Criminal Code also does not provide a precise definition of terrorism, and only lists criminal acts that are considered terrorism (Article 394-b). Additionally, the Criminal Code criminalizes the "terrorist organization" (Article 394-a), as an act that involves the formation of a group, gang, or other criminal entity for the purpose of committing acts classified as terrorism, i.e. that acts that typically involve violence with an aim of spreading fear, or insecurity among citizens. The Code criminalizes as well the "financing terrorism" (Article 394-c), and provides additional qualifications for the terrorist threats against constitutional order and security (Article 313), as well as the acts that are considered international terrorism (Article 419).

In the attempts to align with international standards and strengthen national security, with the amendments in 2014, the Criminal Code introduced the criminal act of "Participation in Foreign Army, Police, Paramilitary, or Parapolice Formations" (322-a). According to this, any individual who unlawfully organizes, recruits, transports, equips, trains, or otherwise prepares a person or group to participate in such formations outside the territory of North Macedonia is subject to a prison sentence of a minimum of five years. Additionally, Paragraph 2 of this article criminalizes activities that directly or indirectly involve securing, providing, or concealing financial resources, funds, assets, or equipment intended to support such actions, classifying them as ancillary offenses. The participation or training of Macedonian citizens in such formations that are outside the territory of the state is envisaged

as a special form of this crime and is punishable by at least 4 years in prison. However, in the case where Macedonian citizens have the citizenship of the state in whose military and police formations they participate or if they are members of its military, paramilitary, or police forces but under the control of internationally recognized governments and organizations, then there is no illegality. The actions related to the incitement to such actions is sanctioned as well (Article 322-a) with a prison punishment of at least four years. A qualified form of this crime if these activities are committed against a child, for which a prison sentence of at least 5 years is predicted. Additionally, anyone who hides the perpetrator of the crime, or helps prevent the discovery of the crime or the perpetrator by hiding the means with which the crime was committed, the evidence, or in any other way, shall be sanctioned, with a prison sentence of one to five years (Article 322-a, paragraph 6). Within there is also a possibility of effective repentance, and for anyone who contributes in the finding of the perpetrators may be released from punishment.

The Law on Prevention of Money Laundering and Financing Terrorism regulates the measures, actions, and procedures that entitle competent authorities and bodies to undertake them in order to detect and prevent money laundering, terrorist financing, and related criminal offenses. A new Law entered into force in July 2022 and aligned it with the EU Directive 2018/843. Although the Law entered into force, there are related challenges considering the implementation of the legislation and further challenges, such as alignment of the Macedonian legislation with EU Directive 2018/1673 on combating money laundering (European Commission 2024).

The Law on Execution of Sanctions (LES) governs the enforcement of penalties for criminal offenses and misdemeanors, including imprisonment. It establishes fundamental principles for prisoner resocialization and defines the organizational structure of penitentiary and educational correctional institutions within the country. LES is a legal basis for developing strategic documents, bylaws, and other regulations related to the execution of sanctions, particularly those concerning the rehabilitation of inmates. Additionally, this law guarantees convicted individuals the right to participate in resocialization programs, which include work, education, leisure activities, sports, recreation, and medical or psychological treatment (Article 169). Convicted persons, among other rights, have a guaranteed right to education and work. This attention for convicted persons needs to be not only during the execution of the prison sentence, but also after its serving, with providing assistance upon their release from prison. The assistance should provide food and accommodation, advice on choosing a place of residence, harmonizing family relationships, finding employment, completing vocational training, providing financial assistance to cover the most necessary needs, as well as other forms of support.

2.3. **RRR of the FTFs within a Good Governance Framework**

These RRR programs typically target individuals radicalized to violence, across different stages of disengagement. Such initiatives often combine prison-based interventions with community-level aftercare efforts, following the prison release. The possible programs may provide vocational training, psychological counseling, ideological dialogue, employment support, and other tailored services aimed at preventing relapse into radical networks (OSCE 2018). Within the quality of prison environments is a critical factor since poorly managed facilities can intensify extremist dynamics (Liebling & Hamm 2015). However, prison-based interventions alone are insufficient. Effective reintegration builds on broader, long-term strategies to prevent violent extremism by addressing the structural drivers that enabled radicalization in the first place—such as socioeconomic exclusion, institutional mistrust, and

community stigmatization (Holmer & Shtuni 2017). Therefore, the sustainable rehabilitation outcomes depend on multi-layered support systems that extend beyond criminal justice and prioritize social cohesion, human dignity, and equal opportunity. In parallel, governments must engage a diverse network of organizations capable of contributing specialized expertise to both the planning and implementation of these efforts. This preventive and community-based dimension of counterterrorism should draw upon a wide range of social actors—such as teachers, social workers, and community leaders of various ages and genders—who collaborate closely with traditional security stakeholders, including policymakers, senior government officials, police, and intelligence services (Zeiger 2016). Such cooperation requires a coordinated, multi-sectoral approach in which reintegration is understood as a comprehensive process through which former fighters regain civilian status and secure access to legitimate employment and stable income. At its core, this represents a social and economic transition that contributes to the broader development of the country, and reflects a shared societal responsibility (Gleichmann et al. 2004). In other words, well-designed rehabilitation and reintegration programs for returned foreign fighters are essential not only to prevent future acts of violence but also to curb further radicalization, particularly among younger generations, i.e., to strengthen community resilience against violent extremism (Holmer & Shtuni 2017).

The reintegration and rehabilitation programs for individuals associated with terrorism are necessary for society protection, and to be effective, require tailored intervention strategies that should be founded on the principles of good governance. As highlighted by the Radicalization Awareness Network (RAN 2017), any approach to rehabilitation must be rooted in democratic values that guarantee meaningful participation in social processes, particularly for vulnerable groups such as returned foreign terrorist fighters (RFTFs). Their inclusion in political, public, and community life is fundamental for rebuilding trust and fostering active citizenship. Establishing an environment where civil and political rights—including freedoms of association and expression—are fully protected constitutes the bedrock for successful reintegration (RAN 2017). These processes must be situated within a society that is committed to the rule of law and respects human and minority rights. Equal access to justice, impartial law enforcement, and an independent judiciary contribute to a sense of security and fairness that are essential for transformative social reintegration (Gleichmann et al. 2004). Only when these principles are upheld can it be expected that those individuals will genuinely regain a sense of belonging and social recognition, i.e., they provide opportunities for positive behavioral change. Moreover, programs must demonstrate transparency in their intentions as well as credibility among actors involved, since legitimacy is critical for trust-building and long-term success (Holmer & Shtuni 2017). Equally important is to recognize that there is no universal model that fits all contexts.

Despite less precise legal definitions within a broad national, regional, and international frame, there are perceived security worries related to the FTFs, especially to the returned ones. Those can be addressed only through an appropriate RRR model. Since this topic requires an interdisciplinary approach, much efforts are needed within the national research discourse. To address this gap, it is important not only to understand this complex phenomenon, but as well to provide solutions that can help in institutional efforts to effectively deal with it.

3. Methods

This research employs a qualitative methodology based on the analysis of existing normative frameworks, institutional practices, and secondary data related to individuals convicted of terrorism in North Macedonia and its RRR efforts involving government agencies, prisons, local authorities but as well as the community. The study includes a detailed legal and policy review of national strategies, laws, and operational procedures relevant to the management, rehabilitation, and reintegration of returned foreign terrorist fighters (RFTFs), both currently serving prison sentences and those released into the community. Data were drawn from national and international reports—including annual publications of the Directorate for Execution of Sanctions, findings of the Ombudsman, assessments by the European Committee for the Prevention of Torture (CPT), and other independent monitoring bodies—to provide a comprehensive understanding of the functioning of the penitentiary system and identify systemic gaps. Additionally, the research incorporates insights from prior academic studies and evaluations to assess the implementation of RRR measures. Gender considerations, community impact, institutional roles, staff capacities, and operational conditions were also examined to ensure a rounded understanding of counterterrorism efforts. The methodological approach thus integrates legal, institutional, and operational dimensions to produce evidence-based findings and actionable recommendations for strengthening the Macedonian counterterrorism framework.

4. Institutional efforts towards RRR of RFTFs

4.1. Peace, justice, and strong institutions (SDG 16)

The current security challenges, within the broader geopolitical context of ongoing conflicts in Ukraine, the Middle East, and regional tensions in Kosovo, are significantly impacting North Macedonia as a multicultural and multiethnic society, with potential spillover effects from global conflicts. The presence of ISIS-affiliated individuals and sympathizers further heightens security risks. Authorities acknowledge the risk of citizens being recruited into foreign wars (which is punishable under domestic law), and these concerns extend across the Western Balkans, particularly given the role of technology and social media in spreading extremist ideologies (Nexus 2022; Nexus 2023). To address these issues, and despite being one of the smallest members of the Global Anti-Terrorist Coalition, North Macedonia has developed a comprehensive reintegration strategy for RFTFs, aiming to integrate them into society and prevent further radicalization. At the policy level, the National Counterterrorism Strategy (2023–2027) and the National Strategy for Combating Violent Extremism (2023–2027) are in place. Those two strategic documents have been coordinated by the National Committee, which is a governmental body supported by the Inter-Ministerial Working Group. The system is comprehensive but in the same time a complex one, which makes it difficult to navigate. For instance, RFTFs serve their sentences in penal institutions, which are part of the national prison system, organized through a network of Penal and Correctional-Educational Institutions, supervised by the Directorate for Execution of Sanctions. For the success of this legal entity within the Ministry of Justice, it needs to collaborate closely with the National Coordinator, particularly through officials involved in the Inter-Ministerial Working Group for RRR. However, this collaboration also extends to other committee members, depending on the nature of the tasks and the involvement of specific institutions required to achieve strategic objectives (Nexus 2023).

4.2.Initiatives supporting education and employment for returnees (SDG4 & SDG8)

Reintegration measures are connected with successfully overcoming the challenges and realization of the programs (such as adequate planning and ensuring sufficient financing), and more structured social activities, raise the general awareness and increase the community responsibility and ability for acceptance. Involving families, community members, and civil society organizations is in line with the "whole-of-society approach," which envisions a role for multiple sectors and civil society actors in prevention, intervention, disengagement, and rehabilitation programs. Considering the Macedonian context, notable on a general level, the community accepts FTF returners without big problems or prejudice, and in essence they are not seen as a great security threat (Nexus 2022).

The central government cooperates with the local self–government units, and this cooperation has been institutionalized with agreements signed between the National Committee and the municipalities, as well as with the Association of the local self–government units (ZElS). The main idea behind it is to strengthen the local communities' resilience so they can actively take part in RRR processes (Nexus 2022). Within this frame some activities have been taken towards raising awareness among the citizens, such as trainings for local youth councils or workshops for local multidisciplinary teams. However, the targeted measures are lacking. The assistance programs, such as active employment measures, skills acquisition, and assistance in establishing cooperation with the business sector, are general and apply to all categories of individuals who are at social risk. Despite not being seen as a threat, this vulnerable category of individuals who have served a prison sentence for terrorism face difficulties in finding employment within companies. The greatest obstacles are fear, discrimination, public condemnation, but as well as the lack of appropriate work skills (Vanchovski, Shikova, Musliu 2020).

The RRR of convicts is a main priority of the probation service. That is organized in cooperation with several institutions such as the Centre for Social Work, National Agency for the Employment, Public Health Institutions, Ministry of Internal Affairs, Public enterprises formed by the municipalities, non-governmental sector, etc. It is done in accordance with the goals set in the individual program of the former convict and aims to achieve the main priorities under supervision of probation service (Nexus 2022). This process means adapting a former prisoner to a new situation, but in fact applies to all former convicts, and it is not customized for RFTFs. Additionally, as a part of this multisectoral approach, the financial assistance is provided to these socially disadvantaged persons; nevertheless, the Law on Social Protection does not legally categorize the RFTFs as a vulnerable group of citizens, meaning after a life in prison, they are left without any financial support. That can be problematic considering that often the financial motive is a predominant factor in caring the decision to join foreign armies at the first place (Vanchovski, Shikova, Musliu 2020).

4.3.Gender Dimensions (SDG5)

Gender plays a critical role in understanding the dynamics of FTFs and the strategies required for effective reintegration. EUROPOL estimates that approximately 11% of European FTF returnees are women (Europol 2020), and global assessments numbered the female population between 13–20% of all FTFs (International Centre for the Study of Radicalization 2018). Although media narratives often stereotype female recruits as "jihadi brides," research demonstrates significant diversity in their backgrounds, motivations, and roles (Shapiro & Maras 2018). The general practice points out that while many women have been associated with non-combat functions, the ideological embrace of violence and the

possibility of active militant engagement must not be overlooked. However, North Macedonia has adopted a human-security-based approach, and by 2023, 15 women and 28 children, citizens associated with ISIS, were the state successfully repatriated. Unlike the international trends, in the Macedonian context, women are largely treated as persons at risk rather than criminals, as authorities consider them to have travelled primarily to accompany husbands. Consequently, unlike male returnees, no women have been prosecuted under foreign fighting legislation. As for the others, the reintegration efforts are guided by a National Plan and standard operating procedures emphasizing education access, psychosocial support, and work within communities through multidisciplinary teams. However, significant gaps persist, including a lack of gender-responsive indicators, uneven local institutional capacity, limited financial assistance, and legal challenges related to civil documentation for children born in conflict zones.

4.4.Community integration (SDG10)

In the global effort to prevent violent extremism and counter international terrorism, counterterrorism measures have become central to security discourse over the past two decades. Governments increasingly acknowledge the importance of addressing the underlying "root causes" or drivers of radicalization to develop effective policies and programs that can mitigate or eliminate these initial triggers. Such drivers vary widely, ranging from ideological motivations and personal or family influences to charismatic leadership, socioeconomic marginalization, political grievances, material incentives, and desires for retribution—each contributing to an individual's path toward radicalization in different ways (Zeiger 2016). Effective prevention of radicalization depends strongly on localized, community-driven initiatives, particularly within schools and municipal-level structures. Strengthening the capacities of local prevention/countering violent extremism actors and raising public awareness support social resilience and reduce stigmatization toward returnees. Civil society organizations play a crucial role by offering psychosocial support, trauma-informed services, vocational training, and pathways to employment—critical factors in preventing frustration and renewed distrust toward state institutions. Training programs for social workers, psychologists, teachers, and frontline practitioners contribute to reducing stigma and facilitating smoother reintegration for returnees and their families. On the other hand, in North Macedonia, the religious communities remain underutilized despite their influence within local contexts. While strategic national frameworks emphasize broad social engagement—including religious leaders—faith-based actors are only informally involved (Horizon Civitas 2024).

5. Discussion: Main challenges and some positive steps

Recently, the EU raised concerns that the country is only moderately prepared to combat terrorism, reintegrate FTFs and address radicalization in prisons. The EU is critical towards the absence of an adequate program for reintegrating FTFs into their communities, but as well points out that there are still staff shortages, underfunding, and overlapping institutional responsibilities. Within these remarks, it is pointed out that the cooperation between central and local institutions needs to be strengthened, as well as information sharing in the municipalities where returnees settle after serving their sentences. Additionally, the steps need to be taken within prison institutions aimed at preventing radicalization, since as they are set, they may facilitate it (European Commission 2024) (n.b. the FTFs are not separated from other prisoners).

As the other faced challenges, it may be listed as the need for more comprehensive implementation of the set strategies. While Government has introduced legal and financial measures to monitor returnees and launched collaborative reintegration programs involving state institutions, NGOs, and international organizations, significant obstacles remain, among them overlapping responsibilities between governmental institutions, local authorities, and penitentiaries (Nexus 2022). Alongside, it is important to note that institutions in North Macedonia operate with discretionary powers embedded in numerous laws. These powers are often granted through vague and poorly defined provisions, which allow institutions excessive flexibility in decision-making. While such flexibility is intended to enhance efficiency, it frequently results in abuse of power, undermining the public good and exceeding legal and ethical boundaries (Gjorgjievski & Vrglevski 2023). Considering the inmates convicted of terrorism-related offences, the broader institutional culture has additional challenges, including corruption and mistreatment by prison staff. However, these problems are symptomatic of the general conditions and daily experiences faced by all prisoners, not just those convicted of terrorism-related crimes (Dimoski 2024).

Additionally, a stronger gender-sensitive framework is necessary to ensure that returnee women and children do not remain marginalized, which could increase vulnerability to radicalization (Brown & Mohammed 2021). Integrating gender dynamics more fully into prevention, rehabilitation, and reintegration policies remains essential for shaping resilient communities and advancing broader sustainable security goals in North Macedonia. Within this frame, establishing of structured, multi-agency approach to community reintegration remains essential. This includes expanding cooperation between local authorities, CSOs, and religious bodies. Developing a clear policy roadmap for faith-based engagement—especially with individuals convicted of extremist offences—would strengthen North Macedonia's comprehensive response and contribute directly to community safety, inclusion, and long-term prevention of radicalization.

For EU and international counterparts, the prison radicalization is arguably the most concerning aspect. The issues are raised on the staff shortages in prison police, but also in the lack of specialized training to address such threats (Vanchoski, Shikova, and Musliu 2020; RAN 2017). The shortage is not only in qualified resocialization experts, as well as post-release care practitioners (Nexus 2022; Council of Europe 2023). Additionally, considering the terrorism issues, not only weak reintegration efforts for returnees—especially the lack of effective intergovernmental coordination (both horizontal and vertical) is one of the major challenges, but also the lenient sentencing for terrorism related offences in comparison with EU and international practices standards, and this remains to be further addressed.

Despite these inconsistencies, there are also some positive developments. For example, more recently, all case files, release assessments, psychological evaluations, and individual RRR plans have been integrated into a specially created database managed by the Ministry of Social Policy, which has taken over coordination in this area. All institutions (including prisons, probation services, etc.) that possess documents related to RFTFs are required to submit them to the Ministry so they can be included in the database. When necessary, these institutions can access the information in an integrated manner. A significant portion of these documents is also submitted to the courts for various legal purposes. Access to the database is fully available to the National Security Agency, multidisciplinary teams, and all relevant organizations and institutions through formal requests for information, as provided by law. However, access is strictly regulated, and the Ministry makes the final decision based on whether the requesting party has a legitimate interest. In addition to institutional files, the database also includes informal sources such as NGO evaluations, donor reports, and similar documents intended to support a more comprehensive approach to

the issue. Nonetheless, a significant barrier remains: a lack of trust between institutions and civil society organizations, as well as ongoing deficiencies in communication and coordination.

This research has some limitations, and they need to be taken into account. The study mainly relies on secondary sources, official reports, and existing literature, whereas the interviews, fieldwork, or direct engagement with returnees, prison staff, or policymakers were part of the previous undertaken research that relied primary on empirical data. This research is based on an institutional practice that sometimes depends on publicly available documents, although some information is gained through direct contact with the relevant stakeholders. As a result, this study partially reveals informal and non-documented coordination problems within institutions. Therefore, the potential bias in available sources needs to be taken into account. Additionally, while gender is discussed within this study, the empirical data on women and children returnees in North Macedonia remain scarce, constraining deeper gender-responsive analysis. Nevertheless, this study (same as the previously undertaken) has a restricted scope of evaluation since there was a possibility to assess legal frameworks and policy implementation, but not to measure the actual effectiveness of reintegration outcomes or long-term recidivism. That should be part of other, much more structured evaluation efforts, and it is a possible topic for future research.

6. Conclusion

Human Security and Sustainable Development are deeply interconnected approaches that place people's well-being at the center of global governance. Human Security is a condition for development since conflict, violence, and insecurity undermine development efforts. North Macedonia continues to demonstrate a strong commitment to counterterrorism engagements, particularly in fulfilling the objectives established in the Joint Action Plan on Counterterrorism for the Western Balkans. The country maintains cooperation with EU partners, while national legislation is broadly aligned with EU and international counterterrorism standards (European Commission 2024). However, further alignment is necessary. Although the terrorism-related challenges are something new that faces North Macedonia, there is a solid legal foundation to address such issues. However, ongoing efforts are required to refine sentencing practice, implement effective post-release monitoring, and ensure close coordination among stakeholders. The country remains committed to international collaboration and adherence to human rights principles, and it is an active participant in the global fight against violent extremism and terrorism—dedicated to ensuring the security and stability of the region. Nevertheless, the evolving geopolitical context and emerging security threats necessitate continuous vigilance and adaptability in national strategies. While the existing strategies and initiatives appear wide-ranging, their success depends on sustained coordination, monitoring, evaluation, and adaptation to new challenges. Additionally, for the success of these efforts and for overcoming the current challenges, it is essential to clarify the roles and responsibilities of local and central institutions involved in counterterrorism and the prevention of violent extremism. To support early detection and effective intervention, coordination between national and local teams must be strengthened; institutional capacity should be enhanced; mandates and available resources clearly defined; and information sharing improved. That is necessary since human security, as a part of sustainable development, enhances people's lives, dignity, and opportunities. Only with joint efforts and with a comprehensive agenda, these outcomes can be inclusive and lasting, making the society resilient and capable to address current and future challenges that faces.

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MULTI-LIBERAL-EUROPE: A FREE SOCIETY THROUGH DIFFERENTIATED INTEGRATION

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ABSTRACT

***Introduction**: This paper examines the relationship between two major ideological traditions in the European integration process—liberalism and European federalism—and explores the potential for their synthesis into a coherent political framework.*
***Methods**: The central research problem concerns the persistent heterogeneity of European Union (EU) member states with respect to their capacities and preferences for deeper integration, which continues to obstruct the realization of a free and united Europe. The study aims to investigate whether existing institutional mechanisms can facilitate the convergence of liberal and federalist ideas. The guiding research question is: Can liberalism and European federalism be combined into a viable political model for the EU through the mechanism of enhanced cooperation? Methodologically, the paper employs a theoretical analysis that integrates ideological inquiry with institutional examination. Attention is given to the provisions of the Lisbon Treaty, with a focus on enhanced cooperation as a pragmatic means of enabling differentiated integration. This framework is used to assess how diverse member states might simultaneously advance liberal and federalist objectives without requiring uniform participation.*
***Results**: The findings are presented in the conceptual model of Multi-Liberal Europe, a scenario in which member states apply liberal principles and federalist stages of integration in a differentiated manner.*
***Discussion**: This model provides a flexible, transitional mechanism for reconciling divergent national trajectories while maintaining broader momentum for integration. Although conceived as a provisional arrangement, the model aspires ultimately to contribute to the long-term vision of a Free and United Europe.*

Keywords: Liberalism, Federalism, Multi-Speed Europe, Differentiated Integration, EU

INTRODUCTION

This paper represents a theoretical journey into two distinct ideologies and explores the possibility of their emergence into a new ideological amalgam through a pragmatic institutional mechanism.

The first ideology is liberalism, specifically understood as classical liberalism, and its reflection on social issues. The second one is (European) federalism, partially integrated into the structure of the European Union. The ideological concept, derived from their possible

emergence, is that of Multi-Liberal-Europe, or differentiated integration, and the institutional basis is the mechanism of enhanced cooperation, as stipulated by the Lisbon Treaty.

Multi-Liberal Europe is a concept and/or a potential political scenario where the member states of the EU, non-uniformly, are applying the activities of liberalism and federalism. The concept is graphically presented as a federal-liberal core, surrounded by less integrated member states.

Liberalism and federalism involve the transfer of state sovereignty, primarily to individuals and, secondarily, to the federal level of governance. The shift in sovereignty is a component of the broader social change, as envisioned by the four liberal integration activities: *liberalization*, *privatization*, *decentralization*, and *supranationalization*. Furthermore, federalism, or the political integration toward federalism, encompasses the achievement of particular integration stages, such as Ad Hoc intergovernmental cooperation, institutionalized intergovernmental cooperation, Institutionalized intergovernmental coordination, partial supranationalized *integration*, and *Full (political) integration*.

Differentiated integration refers to processes in which member states progress through various stages of integration according to their preferences and capacities. The conceptual framework of Multi-Liberal-Europe could serve as a *tool* for accommodating member states' diverse capacities and preferences regarding the stages and processes of federalism and liberalism integration. The tool is expected to be of temporal significance, while the goal is to achieve fully federal and liberal European integration, as articulated in the vision of Free and United Europe.

LITERATURE REVIEW

The paper's literature review is based on three primary sources. Namely, the first source is classical liberal literature, the second, federalist literature, and the third, literature on the phenomenon of differentiated integration.

First of all, the classical liberal literature involves works from **Friedrich A. Hayek**, namely his *The Road to Serfdom* (The Institute of Economic Affairs, 2005); *Individualism and Economic Order* (The University of Chicago Press, 1948); *The Constitution of Liberty* (The Definitive Edition, Routledge, 2011); *The Intellectuals and Socialism* (The University of Chicago Law Review, The University of Chicago Press, 1949). **Ludwig von Mises** and, in particular, his masterpiece *Human Action: A Treatise on Economics* (Ludwig von Mises Institute, Auburn, 1998) are among the foundational works used in developing the first part.

The second part, identified with *Federalism - Global and European* is based on the following literature: **Immanuel Kant** - *Toward Perpetual Peace and Other Writings on Politics, Peace, and History* (Yale University Press, 2006); **Emery Reves** - *The Anatomy of Peace*, (Arbinger Institute, Berrett-Koehler Publishers, 2006); **Altiero Spinelli & Ernesto Rossi** - *The Ventotene Manifesto* (The Altiero Spinelli Institute for Federalist Studies, 2013); **Friedrich A. Hayek**, namely his *The Road to Serfdom* (The Institute of Economic Affairs, 2005); *Individualism and Economic Order* (The University of Chicago Press, 1948); and **Ilya Somin** - *A Cosmopolitan Case against World Government* (*FEE Stories*, Foundations for Economic Education, 2017).

The third part, the one dedicated to differentiated integration is inspired by the following works: **Jean-Claude Piris** - *The Future of Europe, Towards a Two-Speed EU?*, (Cambridge University, New York, 2012): Giandomenico Majone - *Europe as the would-be world power: The EU at Fifty* (Cambridge university press, 2009); and **Jan-Emmanuel de Neve** - The European Onion? How Differentiated Integration is Reshaping the EU (*Journal of European Integration, Vol. 29, No. 4*, University of Oxford, 2007).

METHODOLOGY

The central research problem concerns the persistent heterogeneity of European Union (EU) member states with respect to their capacities and preferences for deeper integration, which continues to obstruct the realization of a free and united Europe.

The study aims to investigate whether existing institutional mechanisms can facilitate the convergence of liberal and federalist ideas.

The guiding research question is: Can liberalism and European federalism be combined into a viable political model for the EU through the mechanism of enhanced cooperation?

Methodologically, the paper employs a theoretical analysis that integrates ideological inquiry with institutional examination. Particular attention is given to the provisions of the Lisbon Treaty, with a focus on enhanced cooperation as a pragmatic means of enabling differentiated integration. This framework is used to assess how diverse member states might simultaneously advance liberal and federalist objectives without requiring uniform participation.

I. LIBERALISM

One of the most fundamental questions in political philosophy and the social sciences concerns the optimal political organization of a society that enables individuals to secure their existence and achieve well-being.

Various schools of thought and traditions offer different approaches to this inquiry. While some have been realized in specific social contexts throughout history, most have failed to achieve their goals.

1. Meaning & Ideology

A tradition that offers an answer to this question and has been consistently realized across various social realities is liberalism. The contemporary understanding of liberalism covers numerous variations. However, this paper will focus on the schools and traditions of *classical liberalism*.

The broader meaning of *classical liberalism* or *(big-tent approach) libertarianism* (Boaz, 2019) involves schools and traditions inspired, related, and represented by John Locke, Adam Smith, David Hume and Scottish Enlightenment tradition, John Stuart Mill, Manchester School of Economics, Frederick Bastiat and French Liberal School, Individualist-anarchism tradition, Austrian School of Economics, Popper's philosophy of Open Society, Anarcho-capitalism, Objectivism, Chicago-School, Public-choice theory, Big-tent approach libertarianism, and other theories providing justifications and interpretations of individual liberty and free society. Furthermore, classical liberalism in a narrow sense is associated with the tradition of Ludwig von Mises, Friedrich von Hayek, Murray N. Rothbard, Peter Boettke, and other notable Austrian School economists (Powell, 2012).

There is debate over whether classical liberalism constitutes an ideology, despite the term's negative connotations. Ideology can be defined as a set of beliefs that reflect, critique, and propose an alternative to social reality, along with strategies for effecting change and *bringing the ideal into reality* (Rothbard, 2010). Accordingly, the concept of ideology comprises three integral components: eidology, ideelogy, and ideotely (Sarkanjac, 2009). Eidology aligns with ideology as a critique of social reality (Ilik, 2012); ideelogy represents the dynamic or the normative aspect of ideology, while ideotely describes the goals and the processes of attainment (Ilik & Ilievski, 2017).

If ideology is understood in this neutral manner, liberalism can be categorized as one. The liberal critique of social reality (*liberalism's* ***eidology***) reflects the dominant approach in handling social issues. This relates to the pervasive role of government in addressing economic and social problems, almost always at the expense of human liberty and efficiency. It is a critique of numerous government activities, such as *initiating wars, violating individual rights, incriminating victimless acts, maintaining a central planning economy, excessive taxation, regulation, and legislation, manipulation of monetary politics, inefficient functioning*, as well as a *failure to deliver (criminal) justice* (Von Mises, 1998; Hayek, 2005). ***Anti-etatism*** is the *eidology* of liberalism.

The liberal alternative to the current social status quo—ideelogy—is one in which the principle of individual self-ownership serves as a fundamental socio-political guiding principle. Building upon the traditions of Locke (2006), Nozick (1974), Rothbard (2002), and Rand (1967), self-ownership asserts the right of an individual to own their body (life), actions (freedom), and the outcomes of those actions (property) (Ilievski, 2016). The axiological system derived from this principle is grounded in values such as peace, individual liberty, private property, freedom of exchange, and non-interference, thereby constituting the moral justification for liberalism. Additionally, the economic rationale of liberalism supports the more efficient allocation of resources within a liberal political framework than within a centrally planned one (Palmer, 2013).

Liberalism aspires to achieve a ***free society***. A free society is characterized by the presence of a night-watchman state (or alternative private governance), spontaneous order, and adherence to the rule of law. The ***ideotely*** encompasses the strategy and the process of societal and politico-institutional change aimed at this goal. The visions of social change in a democratic context presuppose a peaceful approach. The primary method is *educationism* (Rothbard, 2010), where actions are rooted in ideas, and the mission of liberals involves disseminating knowledge through books, pamphlets, articles, lectures, and similar media. Recognizing that ideas thrive within social contexts, there's a clear need to mobilize and organize movements and social strategies. The proponents — *open centers, cadres, or secondhand dealers of ideas (Hayek, 1949) work toward change by providing educational, communication*, leadership development, and networking opportunities. The focus of educationism is on effecting ideological change, believing that once this change is accomplished, *social change* becomes inevitable (Blundell, 2001; Stringham & Hummel, 2010; Boettke, 2016; Ilievski, 2022).

2. Liberalism as an integration process and as a stage goal

To achieve the final goal, first initiated by the ideological shift towards liberalism and second reflected in processes of social change, national governments need to undertake activities such as *liberalization*, *privatization*, and *decentralization*.

Liberalization refers to a governmental approach aligned with the principles of self-ownership and non-interference in the economy. This includes policy inclinations such as reduced taxation, stable monetary policies, transparent and minimal spending, decriminalization of victimless crimes, free trade, open borders, and a relaxed criminal justice system. In essence, it advocates for minimal interference in people's lives and interactions (Palmer, 2013).

Privatization entails the transfer of government-owned businesses and properties to private ownership, along with the marketization of areas previously subject to government regulation (Rothbard, 2002).

Decentralization or ***subsidiarity*** entails shifting authority for necessary collective actions to the lowest (political) level possible (Buchanan, 1975).

The objective of these activities corresponds with the ultimate vision of liberalism, embodied in the concept of a ***free society.*** The goal is operationalized in a peaceful, democratic, and transparent ***night-watchman federation*** and ***states*** (or ***alternative private governance***), ***spontaneous order***, and the ***rule of law*** (Butler, 2013).

The notion of a night-watchman state denotes a strictly limited government, primarily tasked with safeguarding individual lives, freedoms, and property through institutions such as the army, police, and judiciary, and with ensuring the enforcement of agreements between parties (D'Amato, 2018). Moreover, it points to a clear separation of powers (legislative, executive, and judiciary branches) to prevent their potential abuse.

The anarchist tradition emphasizes private governance within a stateless society (Rothbard 2002; Barnet, 2014; Hoppe, 2001; Osterfeld, 1986; Ilievski, 2022).

Spontaneous order (or natural, polycentric, economic) refers to the social order (Ilievski, 2021) that emerges consequently not of human design but of human actions (Hayek, 2011; Bamyeh, 2009; Ilievski, 2015). It arises from the voluntary relations individuals engage in, thereby organically forming societal structures.

The rule of law is the extent to which the law is respected by political elites and citizens.

II. FEDERALISM: GLOBAL AND EUROPEAN

The theory of federalism involves academic traditions and schools that emphasize the *consolidation of political entities into a unified political community*, referred to as *finalite politique* (Kovacevic, 2013). Moreover, it can signify an approach that separates and restructures powers within a unitary state into federal and state levels (Weingast, 1995). Federalism typically bears a geographical dimension, identifying a specific region as the territorial basis for this form of governance.

3. Global federalism

Immanuel Kant developed a philosophical foundation for advocating a global Republic in his work "Toward Perpetual Peace and Other Writings on Politics, Peace, and History" (originally written in 1795). Throughout history, the enduring societal aspiration of idealists, cosmopolitans, humanists, and pacifists has been the pursuit of sustainable and uninterrupted global peace. As one of these proponents, Kant proposed an approach for realizing this aspiration, advocating for the creation of a global federal republic. Additionally, Kant outlined a prerequisite for membership in the federation: only civilized states that adhere to republican governance would be included (Kant, 2006). He strongly believed that a state's internal organization profoundly shapes its foreign policy orientation, thereby making membership in the federation crucial.

In his book "The Anatomy of Peace", published just after the Second World War, *Emery Reves* revived Kant's idea. He remarked, "Our political and social conceptions are Ptolemaic. The world in which we live is Copernican" (Reves, 2006), linking the nation-state to Ptolemaic thought and embracing world federalism as a Copernican solution. Aligned with the Kantian tradition, Reves advocated for universalism and collective sovereignty as means to foster global peace.

While the theoretical notions of global federalism appear progressive and cosmopolitan, they face numerous critiques, including some from liberals. Although liberal

ideals are universal and applicable to individuals (Boaz, 2019), the practicality of establishing a single global government is widely perceived as challenging, if not dangerous, to human liberty. Ilya Somin outlined three primary dangers associated with the concept of global government:

> "Stifling of diversity and competition; elimination of the possibility of emigration and 'voting with your feet'; and the rise of global despotism, perhaps even culminating in totalitarianism" (Somin, 2017).

Friedrich Hayek also warned about this approach, noting that "We shall not rebuild civilization on a large scale". (Hayek, 2005; Bloor, 2019)

4. Euro-federalism(s)

The idea of a European federation is not a new one, nor a uniform one, and at least 2 theoretical interpretations could be introduced - Spinelli's and Hayek's. Although both promote unity and peace among individuals and nations (Fouéré, 1968), their approaches are fundamentally different.

Altiero Spinelli emerged as the major ideologue of Euro-federalism (Ilievski, 2012) during and after World War II, championing the ideotely of *European federation*. He has aimed to ensure peace on the continent and globally. Spinelli authored the "Manifesto of Ventotene: For A Free And United Europe" (1941) in collaboration with Ernesto Rossi while imprisoned by the Italian fascist regime on the island of Ventotene. Although initially a communist, Spinelli later distanced himself from communism, adopting an anti-Stalinist stance (Boucart, 2018). However, the most controversial aspect of his federalism is his pro-statist approach, evident in his vision for European unity. In the Manifesto, remnants of his communist heritage are evident.

> "...in a revolutionary crisis, would be opportune to distribute in an egalitarian manner, in order to eliminate parasitic classes and in order to give the workers the means of production that they need, so as to improve their economic conditions and help them reach greater independence." (Spinelli & Rossi, 2013)

On the opposite end of the *federalist spectrum*, Friedrich Hayek, a prominent figure in liberalism, also articulated his vision of United and Free Europe. This could be termed federal liberalism, emphasizing the liberal foundations of his federalist ideals. Although both Hayek and Spinelli share the primary goal of uniting European countries (Hayek, 1948, 2005; Spinelli & Rossi, 2013), Hayek's conception of Federal Europe is fundamentally liberal. He dedicated two chapters in his books, 'The Prospects of International Order' in 'The Road to Serfdom' (1944), and 'The Economic Conditions of Interstate Federalism' in 'Individualism and Economic Order' (1948), to the question of European unity. His liberal vision of a united Europe can be summarized as:

> "An international authority which effectively limits the powers of the state over the individual will be one of the best safeguards of peace. The International Rule of Law must become a safeguard as much against the tyranny of the state over the individual as against the tyranny of the new superstate over the national communities. Neither an omnipotent superstate nor a loose association of "free nations" but a community of nations of free men must be our goal." (Hayek, 2005)

Following this statement, his federalism serves as an instrument of liberalism, aimed at safeguarding human liberty, free markets, and the rule of law on the continent. Moreover, Hayek believed that certain powers, traditionally held by the nation-state, could neither be "exercised by the federation nor by the individual states... there would have to be less government all round if federation is to be practicable" (Hayek, 1948).

Federico Ottavio Reho, comparing Hayek and Spinelli's federalisms, almost perfectly interpreted the vision of Hayek:

> "...a limited framework for continental openness, not a strong and intrusive central government. It only deals with core federal functions – defence, foreign policy and the four freedoms of the internal market – and it encourages decentralisation and competition, not centralisation and harmonisation." (Reho, 2017).

The main difference among variants of European federalism lies in the roles and authorities of the federation and its member states. While Hayek points to the need for strictly limiting both levels of authority and enabling free markets, Spinelli's approach is embracing a powerful federation envisioned to engage in activities such as central planning, redistribution, nationalization, and other (more or less) socialist policies.

III. EUROPEAN INTEGRATION PROCESSES: DIFFERENTIATED INTEGRATION

After World War II, European integration processes emerged in a diverse form, encompassing political, economic, and differentiated integration. These ideas did not align with Spinelli's or Hayek's ideological principles; instead, they were rooted in the theory of *neo-functionalism* and its resulting *spill-over effect* (Majone, 2009). Neo-functionalism signifies a compromise between intergovernmentalism and supranationalism, blending nation-state unanimity to advance stages of integration with decision-making carried out by supranational bodies.

5. Political and economic integration

Ernst Haas, an eminent researcher of European integration, defines the (political) integration as:

> "The process whereby nations forgot the desire and ability to conduct foreign and key domestic policies independently of each other, seeking instead to make joint decisions or to delegate the decision-making process to new central organs." (Lindberg 1963, 3).

Political integration processes involve states gradually transferring their sovereignty to a supranational entity within a defined timeframe (Castaldi, 2007). Additionally, the term 'political integration' also refers to a distinct stage within this process, highlighting the extent of sovereignty delegated from a national level to a supranational one, particularly focusing on foreign affairs and other crucial domestic policies.

There are five stages in the process of political integration: *Ad-hoc intergovernmental cooperation*, *institutionalized intergovernmental cooperation*, *Institutionalized intergovernmental coordination*, *Partial supra-nationalized integration*, and *Full-integration* (the states are no longer actors of international public law) (Dosenrode 2010). All the higher stages involve the previous ones.

Neo-functionalists argue that the first steps of political integration are initiated by an ongoing economic integration (Heinonen, 2006). Political integration naturally arises at a certain phase of economic integration, triggered by either the spill-over effect or the domino effect (Majone, 2009).

Economic integration involves the delegation of sovereignty and the establishment of supranational institutions in economic areas of public policy, representing a distinct stage within the integration process (Ilik & Ilievski, 2018). This progression is often categorized into five stages: *Free trade cooperation*, *Customs Union*, *Common Market*, *Monetary Union*, and *Economic Union*, which encompasses common monetary and fiscal policies along with

shared institutions (Holden, 2003; Ilievski, 2015). Additionally, each higher stage encompasses and builds upon the previous ones.

Political and economic integration processes are interdependent rather than independent. They are mutually determined, following the spill-over effect, making it impossible to achieve the final stage in each process separately. Economic integration stimulates political integration and vice versa.

While both these conceptualizations function on a symmetrical basis, involving all states on equal terms, another concept of integration emerges, known as *asymmetrical* or *flexible integration*, often referred to as *differentiated integration*.

6. Differentiated integration

Differentiated integration could be identified as the process where member states progress through various stages of integration based on their preferences and capacities (Ilievski, 2015, 2018). This differentiation typically involves two types of member states: one more deeply integrated within the entity, delegating a significant quantity of sovereignty, and another less integrated (De Neve, 2007). The process incorporates at least two integration stages—the *integration core* and the *integration orbit* — within a single integration process (Tekin & Wessels, 2008) as defined by Brandi and Wohlgemuth (2006).

Applied in public policy, differentiated integration manifests as variations in the implementation of European policies (Jakub & Rafał, 2023) and the intensity of members' participation in the European political system (Majone, 2009). These variations are influenced by integration of actors who select policies and express their willingness to participate (Jensen & Slapin, 2010).

Differentiated integration within European integration processes diverges from symmetrical integration, allowing for varying speeds or stages of political and economic integration (Gierlich & Riedel, 2021). This concept covers diverse formal and informal arrangements, whether within or outside the EU treaty framework (Matarrelli, 2012).

7. Models of differentiated integration

The EU has adopted and/or inspired at least three conceptual types of differentiated integration, determined by the variations' nature (Holzinger & Schimmelfennig, 2012). The first one serves the models of ***Two-Speed-Europe*** and ***Multi-Speed-Europe*** (Piris, 2012). The differentiation is perceived as a temporal category, and the process as a tool of achieving symmetric integration, while accommodating member states' preferences.

The second type is based on territorial differentiation, dividing Europe into a more-integrated West and a less-integrated East, represented through the models of ***Core-Europe*** and ***Europe-of-Concentric-Circles*** (Ilik, 2020).

The last type introduces the models of ***Variable-geometry*** and ***Europe-à-la-carte***, both based on the areas of integration (Von Ondarza, 2013).

The models of differentiated integration could be specifically applied in the processes of European integration. Certain member states participate in certain common policies while others do not. A visible example of differentiated integration is the cooperation established within the Schengen Zone and the Eurozone. Additionally, these differentiations are further institutionalized within the Lisbon Treaty (Lisbon Treaty, 2009), which stipulates the mechanism of ***enhanced cooperation*** (Ilik, 2023), framing potential differences in particular areas of integration.

Before the mechanism of enhanced cooperation, *the Open Method of Coordination* was formally initiated by the Lisbon European Council in 2000. It is described as a form of 'soft' law. It is a form of intergovernmental policy-making that does not result in binding EU legislative measures, and it does not require EU countries to introduce or amend their laws (EUR-Lex).

IV. RESULTS: MULTI-LIBERAL-EUROPE

Friedrich Hayek has developed a vision of a united and free Europe rooted in liberal ideas. He advocated that human freedom should serve as the fundamental organizing principle, emphasizing that a market economy is of huge importance for maintaining well-being and prosperity. In his vision, the federation's authorities would be restricted to maintaining an army, conducting foreign policy, and organizing fiscal and monetary policies in a strictly liberal manner.

8. Differentiated liberalism

The realization of federal liberalism's vision covers an incremental process of transforming states. This process involves the transfer of state sovereignties, primarily to individuals (Ilievski, 2015), and secondarily to a federal level of governance. The shift in sovereignty is a component of the broader social change, as envisioned by the four liberal integration activities: liberalization, privatization, decentralization, and supranationalization.

However, not all member states may share identical preferences or capacities for the federal-liberal transformation processes. These divisions raise a potential issue concerning the dominant principle of unanimity in decision-making within the EU. One potential solution could derive from the approach of differentiated integration, based on the experiences within European integration processes. This could involve the application of conceptual models provided by integration theorists to address the challenges arising from diverse state preferences and capacities.

If the mechanisms of differentiated integration could be utilized to support the political and economic integration within the EU, furthermore, they could serve as a tool for advancing federal liberalism in Europe. This would entail an asymmetric fulfillment of liberal activities, gradually aligning with the vision of liberalism in Europe. Implicitly, Hayek suggested the approach of differentiated integration in his work "The Road to Serfdom.":

> "...the need for some such other organization should not form an obstacle to a closer association of those countries which are more similar in their civilization, outlook, and standards." (Hayek, 2005)

If certain European countries demonstrate both determination and capacity to take further steps in the pursuit of liberalism, they could be encouraged to do these within the framework of European integration, thereby serving as a federal-liberal political structure.

9. Model of Multi-Liberal-Europe

Considering the models of differentiated integration, the most suitable for a liberal approach appears to be the model of Multi-speed Europe. This model allows for differentiation, to serve as a tool to gradually achieve a symmetrical, Free, and United Europe. It is anticipated to hold temporal significance in realizing the final vision.

The processes of differentiated integration in liberalism differ from those in political integration, despite both involving the transfer of authorities to the individual and federal levels. However, both political and economic integration, along with liberalism, can be

viewed as integration processes. The former follows a five-stage progression, while the latter encompasses four activities, all carried out by the member states.

The instrumental nature of a Multi-Liberal-Europe lies in stimulating and advancing the integration of liberalism within Europe by fostering various paces of adopting liberal activities. Member states serve as the primary actors, participating in these different paces. Those most deeply integrated in liberalism could form the liberal core of integration, while other states might implement liberal activities to a lesser extent. This liberal core could potentially represent a partial realization of Hayek's vision of a free society. However, the ultimate fulfillment of this vision may occur when all European countries participate in the liberal core.

Furthermore, the model of Multi-Liberal-Europe is not solely dependent on the Multi-Speed-Europe framework. Other models, such as Europe-à-la-carte or Variable-geometry, could also be employed. Member states might choose specific areas in which they wish to promote liberal integration processes. Countries with similar liberal policies could form groups to exchange experiences, offer mutual assistance in achieving higher levels of integration, and serve as examples for those less integrated. The integrational mechanism of enhanced cooperation (outlined in the Lisbon Treaty, 2009), which provides an institutional framework for differentiated integration, could be formally utilized in promoting liberal integration processes.

Finally, achieving a Free and United Europe requires a bottom-up approach, emphasizing the need for decentralized change. In this context, the model of Multi-Liberal-Europe aligns with liberalism as both a strategy and a process toward realizing a free society in Europe. It serves as a political framework that initiates and guides liberal integration processes among member states, facilitating progress towards the final goal of a liberal and united European society.

10. Discussion: Model of Multi-Private Europe?

The variations within the Austrian School of Economics present two contrasting visions of a free society—one being minarchist (as seen in the interpretations of Menger, Mises, and Hayek) and the other anarchist (as represented by Rothbard, Hoppe, and Block). This dichotomy leads to different interpretations of the concept of liberal/libertarian differentiated integration.

While the minarchist perspective aligns with Multi-Liberal-Europe, the anarchist interpretation might be termed as Multi-Private-Europe. The exploration of the anarchist perspective on the concept of differentiated integration could be a subject for future research or a scholarly discussion.

CONCLUSION

Classical liberalism is understood as an ideology that embraces a critique of the social status quo, moral and utilitarian justifications for the idea of individual liberty, a strategy for peaceful social change, and a vision for a *free society*. The main pillars of the ideology are the concept of a night-watchman state (or alternative private governance), spontaneous order arising from human action, and the rule of law, or equal respect for the legal rules in a society. The change towards liberal vision involves three main activities: liberalization, privatization, and decentralization.

On the other hand, federalism is a theory involving academic traditions and schools that emphasize the consolidation of political entities into a unified political community. One of the two forms it can appear in is global and European federalism. European federalism covers the ideas for uniting Europe; however, these ideas are not uniform. Knowing that, Hayek's and Spinelli's version of European federalism can be found at both ends of the federal spectrum. Spinelli's federalism is (more or less) a socialistic one, while Hayek's is a liberal one.

Federalism introduces the processes of political integration, which involves gradually transferring their sovereignty to a supranational entity within a defined timeframe. Furthermore, differentiated integration in the EU embraces the variations in the implementation of European policies and the intensity of members' participation in the European political system. These variations are determined by the preferences and the capacities of member states for moving to the stages of political integration. Differentiated integration is represented by models of *Two-Speed-Europe* or *Multi-Speed-Europe*, *Core-Europe* or *Europe-of-Concentric-Circles*, and *Variable-geometry* or *Europe-à-la-carte*.

Multi-Liberal Europe is a concept and/or political scenario deriving from the model of Multi-Speed Europe, where the member states of the EU, non-uniformly, are applying the activities of liberalism and stages of federalism. Furthermore, it could serve as a tool for accommodating member states' diverse capacities and preferences concerning the federalism and liberalism integration processes. The tool is expected to be of temporal significance, while the final goal is achieving a liberal European integration, manifested in the vision of Free and United Europe.

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EFFECT OF COMBUSTION CHAMBER DIAMETER ON NOX EMISSIONS IN A LIQUID FUEL COMBUSTION STEAM BOILER

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ABSTRACT

Introduction: *Industrial boilers are significant stationary sources of nitrogen oxides (NOx). Reducing the volumetric load rate of the combustion chamber through geometric changes can reduce the maximum flame temperature and NOx formation, but limited field data exists under fixed operating conditions*

Methods: *An A/B comparison was performed on a 495 kW combustion chamber boiler configured with two combustion chamber diameters, keeping the rated output and heating surface constant: Ø 550 mm (boiler I) and Ø 650 mm (boiler II). At half load (Q = 272 kW) and full load (Q = 495 kW), the NOx concentration (mg/m³), thermal efficiency (η), and combustion chamber outlet temperature (°C) were measured. The volumetric load rate of the combustion chamber Qvf (kW/m³) was calculated for each configuration. The mass emission rates were estimated based on a measured flue gas flow rate of ≈770 m³/h per boiler.*

Results: *Increasing the combustion chamber diameter from 550 mm to 650 mm reduced Qvf by 29% (1358 → 963 kW/m³) and lowered the NOx concentration at both loads: from 111 → 101 mg/m³ (half load) and 124 → 113 mg/m³ (full load).At full load, the outlet temperature dropped from 920 °C (Ø550) to 903 °C (Ø650). Thermal efficiency remained almost unchanged (92.3% compared to 92.1% at full load; 93.2% compared to 92.8% at half load; ≤0.4 percentage points difference). The reduction of 11 mg/m³ at full load corresponds to an emission reduction of ≈8.5 g NOx/h (≈85 g over 10 h).*

Discussion: *Reducing the volumetric load rate of the combustion chamber by slightly increasing the combustion chamber diameter leads to a consistent reduction in NOx without any loss of performance or significant loss of efficiency under real operating conditions. Optimizing the combustion chamber geometry is a practical, cost-effective way to control NOx in industrial liquid fuel boilers.*

Keywords: NOx; Industrial boilers; Combustion chamber geometry; Volumetric combustion chamber load; Combustion temperature; Emission control

INTRODUCTION

Nitrogen oxides, commonly referred to as NOx, have become the focus of scientific research and regulatory authorities in recent years, as they have been identified as one of the main causes of numerous harmful phenomena. Their harmful effects are linked to:

-effects on human health,
-reduced visibility and the formation of photochemical smog as a result of reactions between NOx and organic substances under the influence of sunlight,
-the depletion of ozone in the upper layers of the atmosphere,
-the formation of harmful ozone in the lower layers of the atmosphere,
-the formation of acid rain.
From an environmental and health protection perspective, the most important nitrogen oxides are:

-NO – nitrogen monoxide,
-NO_2 – nitrogen dioxide,
-N_2O – nitrous oxide.

More than 90% of the nitrogen oxides released during combustion processes are in the form of nitrogen monoxide (NO), with the remainder being nitrogen dioxide (NO_2). Since nitrogen monoxide is easily converted to nitrogen dioxide in the atmosphere, most environmental regulations treat all nitrogen oxides collectively as NO_2.
Data on the sources of nitrogen oxide emissions show that about two-thirds of total NOx emissions come from combustion processes (Figure 1.1).

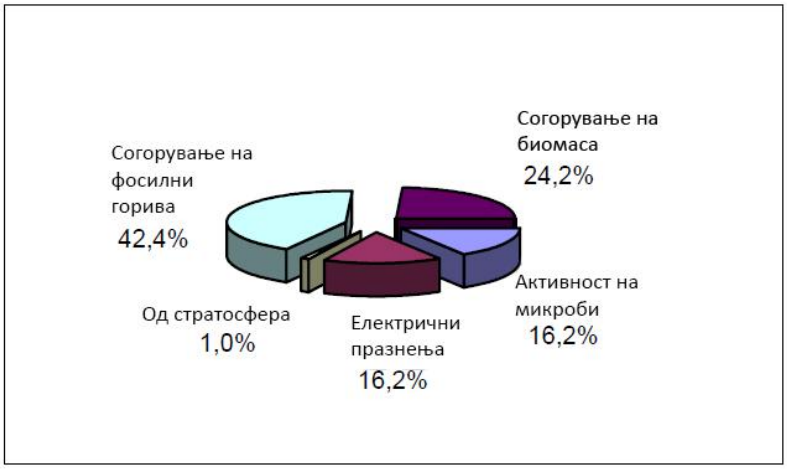

Figure 1.1. Structure of NOx emission sources

These facts have prompted combustion research to develop environmentally friendly solutions, with an increasing focus on striking a balance between the efficiency of combustion plants and minimal environmental impact.

1. MECHANISMS OF NITROGEN OXIDE FORMATION

1.1 Thermal NO (Zeldovich mechanism)

The role of nitrogen from the combustion air in the formation of nitrogen monoxide was explained by Zeldovich. Under stoichiometric conditions, thermal NO is produced by the following reactions:

$$O + N_2 \xrightarrow{k_1} NO + N \quad (1)$$

$$N + O_2 \xrightarrow{k_2} NO + O \quad (2)$$

Reaction (1) represents the first step in the formation of nitrogen oxide. A large amount of energy is required to activate it, which according to Zeldovich is E = 314 kJ/mol, as a lot of energy is needed to break the strong bond in the nitrogen molecule N_2. The high temperature required to achieve this activation energy causes the formation of thermal NO to increase exponentially with temperature. Therefore, reaction (1) is the rate-determining step in the formation of thermal NO. Since reaction (1) only proceeds at a significant rate at high temperatures, this formation mechanism is referred to as thermal.

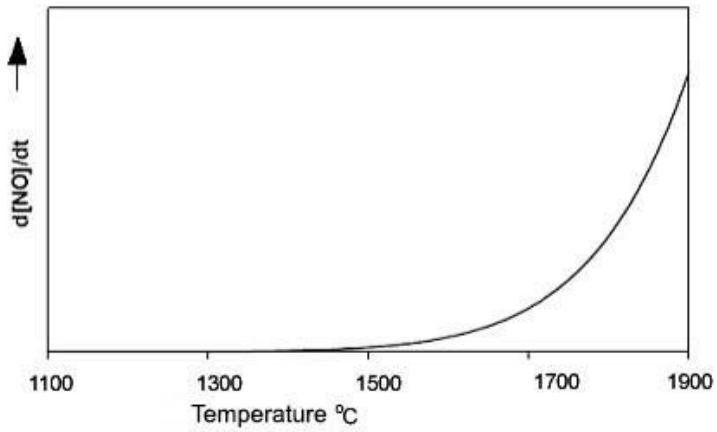

Figure 1.1 Dependence between temperature and the rate of formation of nitrogen oxides

1.2 Prompt mechanism

It has been shown that during the combustion of hydrocarbons, the rate of NOx formation can exceed the rate that would be expected from the direct oxidation of molecular nitrogen (thermal NOx). This discrepancy is particularly pronounced when analyzing the combustion of hydrocarbons under fuel-rich conditions.

This phenomenon can be explained by the formation of nitrogen oxides via a mechanism that differs from the purely thermal mechanism. The process by which nitrogen oxides are formed so quickly—i.e., before they can be formed via the thermal mechanism—is referred to as the prompt mechanism.

2. PRINCIPLES OF NOx EMISSION CONTROL

Measures to control nitrogen oxide emissions can be divided into two main groups:

-Primary measures – directly affect the combustion process by inhibiting certain influencing factors in order to reduce NOx emissions;

-Secondary measures – aim to reduce nitrogen oxides that have already been formed.

The amount of NOx produced during combustion depends primarily on the availability of nitrogen and oxygen, the temperature, the degree of mixing, and the residence

time available for the reaction. Controlling these parameters forms the basis for emission reduction strategies and burner design.

The three basic principles of primary control measures relate to reducing the influence of the dominant parameters that promote nitrogen oxide formation:

-Reducing the temperature,
-Reducing the volumetric heat load in the furnace,
-Reducing the oxygen concentration.

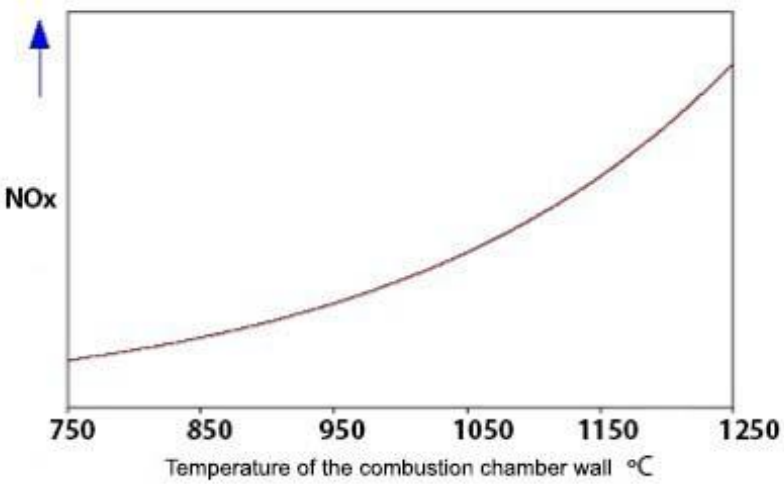

Figure 2. NOx emissions as a function of combustion-chamber wall temperature

3. EXPERIMENTAL RESEARCH AND TESTING

In order to make realistic comparisons of the influence of the design solution on NOx emissions, a study was conducted on two low-pressure steam boilers for heating purposes, each with a maximum output of 500 kW. The two boilers have identical overall dimensions (diameter and length) and a completely identical heating surface. The only difference between them is the diameter of the fire tube: Boiler I has a fire tube diameter of Φ 550 mm, while Boiler II has a fire tube diameter of Φ 650 mm.

The boilers are designed as a block construction (package), are essentially fully automatic, and are fired with heating oil. They are cylindrical, horizontal three-pass boilers: one pass in the fire tube (the combustion chamber) and two passes in the smoke tubes (flue gas pipes).

The boilers operate on the basis of natural water circulation with overpressure on the gas side. The combustion air required for burning the fuel is supplied by a fan that is mounted as part of the burner assembly and blows air into the combustion chamber (flue tube), thereby creating overpressure in the gas duct of the boiler.

In order to enable a comparison between boiler I and boiler II – in particular to determine the nature and extent of the influence of the different design solutions on the flue gas composition and, in particular, on NOx emissions – the composition of the exhaust gases was measured. The measuring points are shown in Figure 3.1. The measurements were first carried out on boiler I with a flame tube diameter of Φ 550 mm and then on boiler II with a flame tube diameter of Φ 650 mm.

In order to obtain reliable and accurate results during boiler operation, the same burner type (Weishaupt WM–L/2-a Monarch) with the same rated output was used for both boilers to avoid errors due to the burner type, combustion control characteristics, and the degree of automation and combustion control. For this reason, the burner was switched from boiler I to boiler II after the measurements on boiler I were completed.

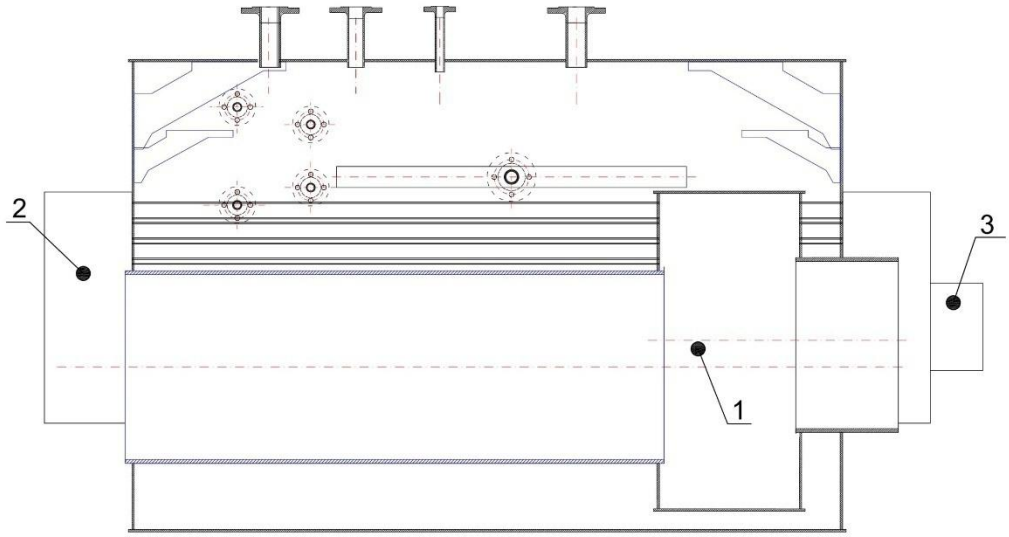

Figure 3.1. Measurement locations (1 – measuring point at the outlet of the first pass; 2 – measuring point at the outlet of the second pass; 3 – measuring point at the outlet of the third pass)

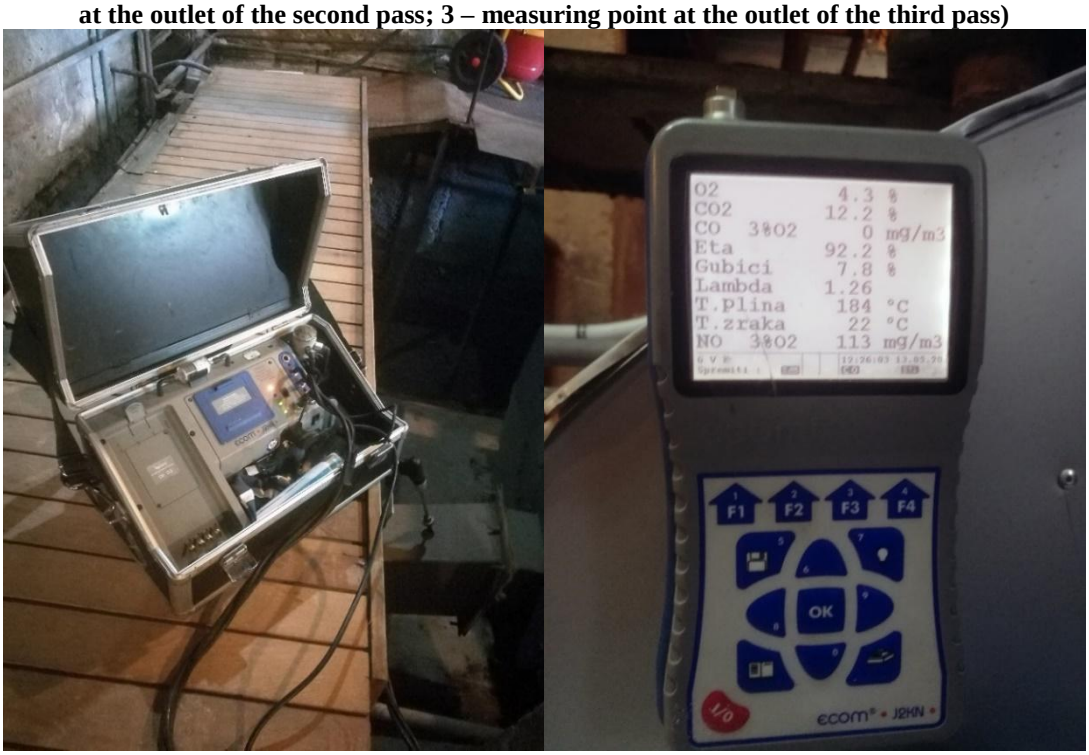

Figure 3.2 and Figure 3.2a. Measurement of the composition of the exhaust gases

4. RESULTS OF THE MEASUREMENTS

After completing the measurements, results were available on the composition of the flue gases in both boilers and on the temperatures at the precisely defined measuring points. The results are shown in Table 4 and in the graphical representation in Figure 4.1.

Table 4. Results of the measurements

	Temperature at the outlet of the combustion chamber[°C]	**Temperature at the outlet of the second pass[°C]**	**Temperature at the outlet of the third pass[°C]**	**Emission of NOx [mg/m3]**	**Thermal efficiency η %**
Boiler I Φ550 during operation at 272 kW	820	278	142	111	93.2
Boiler II Φ650 during operation at 272 kW	805	287	145	101	92.8
Boiler I Φ550 during operation at 495 kW	920	345	183	124	92.3
Boiler II Φ650 during operation at 495 kW	903	353	184	113	92.1

A comparison of the results for the composition of the exhaust gases between boiler I with a flame tube diameter of Φ 550 mm and boiler II with a flame tube diameter of Φ 650 mm reveals clear differences. The tables and graphs show that the NOx emissions in the exhaust gases for boiler I are 111 mg/m³ at a boiler output of 272 kW, while they are 124 mg/m³ at an output of 495 kW. At the same operating loads for boiler II, i.e., at 272 kW, the NOx emissions are 101 mg/m³, while at 495 kW for boiler II they are 113 mg/m³.

5.CONCLUSION

The calculations and measurements carried out for the two boiler variants with different flame tube diameters have yielded several applicable and important findings.

In the first boiler with a flame tube diameter of Φ 550 mm and a burner operating at half power (Q = 272 kW), NOx emissions are 111 mg/m³, while efficiency is η = 93.2%. When the burner is operated at full power (Q = 495 kW) with the same flame tube diameter of Φ 550 mm, the NOx emissions in this case are 124 mg/m³ and the efficiency is η = 92.3%.

In the second boiler with a flame tube diameter of Φ 650 mm and when the burner is operated at half power (Q = 272 kW), NOx emissions are 101 mg/m³, while efficiency is η = 92.8%. When the burner is operated at full power (Q = 495 kW) with the same flame tube diameter of Φ 650 mm, the NOx emissions in this case are 113 mg/m³ and the efficiency is η = 92.1%.

The difference in NOx emissions between the first case, where the diameter of the flame tube is Φ 550 mm, and the second case, where the diameter of the flame tube is Φ 650 mm, is due to the difference in the volumetric heat load of the furnace, i.e., the temperatures in the furnace. Table 4, which lists the measured values, shows that the temperature at the end of the flame tube in boiler I (with a flame tube diameter of Φ 550 mm) is 920 °C, with NOx emissions of 124 mg/m³, and that the theoretically calculated volumetric heat load of the flame tube at a boiler output of 495 kW is Qvf_1 = 1358 kW/m³. In contrast, the temperature at the end of the flame tube in boiler II with a flame tube diameter of Φ 650 mm, measured at the same point as in boiler I, is 903 °C with NOx emissions of 113 mg/m³, and the theoretically calculated volumetric heat load is Qvf_2 = 963 kW/m³.

These measurements show that the difference in NOx emissions between boiler I and boiler II is 11 mg/m³. Considering that, according to theoretical calculations, the volume flow of flue gases in the boilers is approximately 770 m³/h, Boiler II with a flame tube diameter of Φ 650 mm would emit 8470 mg less NOx into the atmosphere per effective operating hour. If we further assume that the boiler operates effectively for 10 hours, the reduction in NOx emissions into the atmosphere would be 84,700 mg/day.

The measurement results show that when comparing the flame tube diameter of boiler I (550 mm) with that of boiler II (650 mm) – an increase in diameter of 17% compared to boiler I, which in this particular case leads to an increase in flame tube volume of approximately 30% – NOx emissions per effective operating hour are reduced by approximately 10%.

These comparisons suggest that increasing the diameter of the flame tube – in this particular case by 100 mm – which, as a design measure, has no impact on the overall design of the boiler and only a minor impact on the production costs of the boiler, leads to a 10% reduction in NOx emissions into the atmosphere. Although 10% may seem small as a percentage, NOx emissions would be reduced by approximately 84,700 g/day or 84.7 kg/day, considering that boilers of this type with a total capacity of approximately 500 MW are installed in Macedonia. This would significantly reduce the impact of NOx on ozone depletion, the greenhouse effect, the formation of acid rain, and negative effects on human health.

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THE EU'S "GLOBAL GATEWAY" INITIATIVE AND GEORGIA'S TRANSIT FUNCTION: STRATEGY, INVESTMENT AND DEVELOPMENT

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ABSTRACT

Introduction: *Modern geopolitical and geoeconomical dynamics are reshaping the significance importance of strategic initiatives in worldwide. The Global Gateway strategy, launched by the European Union in 2021, responds to these shifts by promoting sustainable, secure and interconnected infrastructure in partner countries. This strategy has acquired heightened significance for Georgia, as it advances the country's political, economic, and diplomatic convergence with the European Union within the framework of the Eastern Partnership, while simultaneously consolidating its position as a pivotal transit nexus connecting Europe, the Caucasus, Central Asia, and the Black Sea energy corridor. Recent developments, particularly the U.S.-mediated agreement between Azerbaijan and Armenia concerning the transfer of the Zangezur Corridor - referred to as the "Trump Road to International Peace and Prosperity" - to the United States on a 99-year lease, are expected to significantly reshape the Caucasus dimension of the* Global Gateway *strategy. Although it is difficult to anticipate all the details at this stage, it is both possible and necessary to highlight several essential implications, which are also addressed in this article.*
Methods: *The study applies a qualitative approach based on EU policy documents, international reports, and academic literature, combined with contextual geopolitical analysis of recent regional developments.*
Results: *The findings indicate that the Global Gateway enhances Georgia's potential to attract investment, modernize infrastructure, and deepen cooperation with the EU. At the same time, new geopolitical dynamics—most notably the U.S.-mediated agreement on the Zangezur Corridor, pose uncertainties for the Caucasus dimension of the strategy.*
Discussion:*This article examines the theoretical foundations of the Global Gateway, its sectoral priorities, and Georgia's role within the framework of the strategy. Special attention*

is given to the challenges and opportunities associated with the development of Georgia's transit and energy potential, the deepening of relations with the European Union, and the necessity of strategic choices in a competitive international environment. The study draws on EU and international reports as well as thematic academic literature, providing analytical conclusions and recommendations.

Keywords: Global Gateway, EU–Georgia relations, Infrastructure development, Transit corridor,Energy security, regional integration, Geopolitics, Eastern Partnership

INTRODUCTION

Since the decade of the 21st century, the process of redistribution of international power has been depeening worldwide, fundamentally reshaphing the agenda of global geopolitical and geoeconomic relations. Technological progress, ecological crisis, deficit of energetical security and the reassessment of economical and political model based on western values have prompted leading international actors for mobilizing efforts building stable, partnership-based infrastructural networks within their geopolitical sphere. Against this backdrop, the „Global Gateway", adopted by the European Union in 2021, represents a distinct alternative to China's „One Belt, One Road" Initiative.

The „Global Gateway" is not only a financial mechanisms for funding insfrastructure projects. First of all it grounded the EU's geopolitical ambitious – the aspiration for restoring and expanding its influence in its strategic ambitious where competition among global power is much more intensive. According to the EU's official position, the strategy aims developing high quality, sustainable, climate-neutral and transperent infrastrucuture in areas of transport, digital technologies, health and education.

Within Eastern Partnership, where Georgia plays a pivotal role, this strategy has a central position. In the EU's political discourse, the Eastern Partnership region is framed as a "frontline space" in global competition – a place where the expansion of Western standards and values serves less an instrument of power dominance and more as a tool of political influence. In this context Georgia emerges a natural hub connecting the Black Sea with Caspian Sea and Central Asia. In this geostrategic context, its significance transcends a local function and rise to the level of regional and global equilibrium.

The EU vision for Georgia, particularly in the fields of energy and digital connectivity has been clearly articulated through its support for the projects like Black Sea Submarine Cable Project, the Black Sea Digital Connectivity, the development of Green Energy Corridor and investments in clean energy. These initiatives are not only linked to the dynamics of technological advancement but also represents a new stage of Georgia's political integration, closely tied to the country's foreign policy orientation. At the same time this process can't be viewed to be isolated from the broader geopolitical context. Intensifying competition in the Black Sea region – on the one hand through Russia's efforts for maintaining influence and on the other hand through China's expansion of its interest gives the EU's strategy to be renewed significantly. The European Union seeks asserting its vision not through military means but via economic and normative influence, which can be considered as a defining feature of its external policy identity.

Withing the framework of Global Gateway, Georgia is no longer merely perceived as a geographic bridge – it is becoming a decision-making actor, which needs adopting active political stance for engaging in global processes. The new stage of EU-Georgia partnership is thus based not only on mutual interests but also on the idea of sharing responsibility for global stability, positioning Georgia as an active participant in the western infrastructural space.

„Global Gateway" as an Value-Based Geopolitical and Geoeconomic Integration Model

In the context of XXI century's global competition and multipolarity, the Global Gateway initiative has become of the most strategic instrument of European Union's geoeconomic policy, whos goal is not merely engancing infrastructural connectivity, but expanding EU's influence through value-based approach. This initiative enables the European Union simoltaneously responding the pradaoxical processes of globalization and deglobalization, where competition extends beyond economic resources for encompasses normative values**[Ian Manners, 2002 pg. 235-258]**. At the same time, the main task of European Union is to become a major actor of global politics, which is limited in regulating internal market, but actively participates in formating global order and influences in infrastructural and energy architecture.

In this context, some scholars view the Global Gateway as an continuation of the EU's previous experience, particularly in relation to its neighbourhood policy and enlargement strategies, as it follows the same normative logic – extending the EU's order to neighboring and partner countries. Others argue that the Global Gateway is more ambitious and transcends the scope of the neighborhood policy and it oriented toward a global scale and aims competing with actors such as China, India and the United States. Through this initiative, the European Union seeks presenting itself not merely as a provider of financial resources, but as a value-driven partner investing in long-term stability, rather than short-term politican gain**[Mark Leonard: 2022 pg. 90-91]**. Consequently, the EU's objective is not only increasing its economic influence, but also actively participating in transforming the international order, that makes the Global Gateway a geoeconomic strategy aiming at consolidating power and shaping the rules of international games and thereby reducing dependency on critical infrastrucuture and technolgies**[Natali Tocci, 20211 pg. 3-5]**.

The Global Gateway strategy is particularly significant in infrastructure and economic dimensions, where the EU's goal is to support sustainable, transperent and high-quality projects in partner countries. Thus infrastrucuture development is not merely an instrument of economic progress – it represents a tool of geopolitical positioning, that defines the EU's strategic autonomy on a global scale.

The infrastrucutral dimension of the Global Gateway represents one of its most tangible and visible elements. Its essense lies in developing high quality, sustainable and transperent infrastructural connections that serve both the EU and the long-term socio-economic development of partner countries. The EU aims developing international logistic hubs, which will on the one hand, strength regional connectivity and on the other hand reduce the costs and time of Euro-Asian transit. By creating strategic alternatives to China's „One Belt, One Road" initiative, the EU seeks preserving its global competetiveness.

Energy infrastructure represents another important aspect of Global Gateway and is directly linked to European Union's ecological transformation. The European Union attaches particular attention to promoting clean and renewable energy development, ensuring energy security and its diversification. Strategic energy projects enhancing not only energy stability in partner countries, but also EU's global autonomy**[Natalie Tocci, 2021; pg. 3-5]**.

In the same context, we have to discuss digital connectivity and digitalization, because the play a huge role in the structure of Global Gateway. The EU invests in developing high quality internet connections, data security systems and in developing education and research infrastructure, which enabling partner countries in integrating into global competition**[European Commmission 2021: pg. 5]**.

The economic and financial dimension of Global Gateway represents one of the main key strategic instuments, combining direct investments with economic and institutional supports. It's objective is creating a stable credit environment, foostering the sustainable

development of local economics and promoting innovative business models. This model facilitates long-term economic benefits while strengthening European Union influence in partner countries. Investments are directed toward development of technological and scientific infrastructure, enabling the training of high skilled workforce and the growth of digital economy. Ultimately this leads the modernization of labor market and enhancing global competetivenes.

The financial architecture of the Global Gateway represents one of its most complex mechanisms, integrating public and private sector resources for ensuring project sustainability and long-term efficiency. It includes credit guarantees, public-private partnerships and international investment funds [**European Commmission 2021:pg. 15-17**]. These financial instruments increase transperency and accountability and reducing corruption risks. At the same time, this architecture reflects the EU's long-term vision – strengthening economic interdependence and strategic autonomy. From this point of view, the Global Gateway is no longer a financial initiative – it has become the core element of EU's geoeconomic strategy, integrating economic, infrastructural and value-based dimensions within a unified global framework.

The Global Gateway is not limited with infrastructural and financial measures. One of its central dimension is value based and normative. The European Union seeks strengthening its normative influence in international stage, by promoting democracy, human rights, environmental protection, and transparency in partner countries. This approach aligns with the concept of *strategic autonomy*, according to which the EU strives preserving its freedom in political and economic decision-making while maintaining its influence on international politics — reinforcing its identity as a normative power. A key aspect of normative dimension is establishing development policy and cooperation standards. A Global Gateway ensures that implemented projects in partner countries comply with european environmental, socio-economic and civil standards. This not only increases the effectiveness of these projects, but also strengthening normative authority of European Union.

The „Global Gateway" also encompasses organizational and institutional aspects, enabling the EU actively participate in decision-making process across various regions. It serves as a diplomatic mechanisms reflecting the European Union's efforts maintaining stability, democracy and rule of law in partner countries. Normative goals extent beyond cooperation: the European Union employs institutional engagement as a mechanism for reinforcing standards of public administration and accountability in partner countries. This fosters the development of local democratic institutions, the rule of law and the sustainability projects.

Morover, the Global Gateway is oriented supporting social and cultural development mechanisms, which gives the opportunity to European Union dessiminating its values in those countries, where its political influence is limited. Investments in education and healthcare promotes developing human capital, which in long-term enhancing regional sustainability and competetiveness. Researches have shown that normative component of the Global Gateway significantly strengthens the EU's role as a new type of Global actor – one that relies not only power and economcs, but also on values and institutional engagement for ensuring the sustainability of global order. This normative approach reinforces the infrastructural and financial components, creates systemic balance and ensures long-term partnerships on political, economic and social level.

The Role of Georgia in Global Gateway: Economical, Infrastructural and Value-Based Aspects

The Global Gateway initiative represents one of the most significant strategic opportunities and challenges for Georgia, encompassing both infrastructural-economic and

value-normative dimensions. The European Union views Georgia as a regional partner whose geostrategic position within the Caucasus region grants its special importance in the Eurasian transport and energy networks. Accordingly within the framework of the Global Gateway, Georgia's role involves not only the modernization of material infrastructure, but also the implementation of normative standards, which ensures the country's deeper integration into the European economic and institutional space.

The infrastructural dimension constitutes one of the main pillars of the Global Gateway. The European Union perceives cooperation with Georgia as a means of strengthening transport and energy network, that secure transit stability, energy security and economic integration with European market. Georgia's transformation into transport hub entails the modernization of roads, railways, ports and logistical nodes – reducing transit time and enhancing competitiveness across Eurasian corridor. In parallel, EU investments are directed toward the renewable energy sector, supporting policies of energy diversification and ensuring long-term energy stability for the country.

The development of digital infrastructure is another strategic direction of EU enlargement in Georgia. Investments in high-speed internet networks, data security and digital education strengthen Georgia's technological capacity and lay the foundation for the development of a digital economy. The economic dimension encompasses both public investment and encouragement of private sector participations. EU funded projects in Georgia are often based on Public-Private-Partnership (PPP) model which ensures the sustainability of initiatives and mitigates economic risks.

In Georgian context, the Global Gateway does not solely imply economic or infrastructural support. One of its central components is the value-based and normative dimension aimed at reinforcing democracy, the rule of law, human rights and principles of transparency. The European Union is striving aligning its economic and institutional assistance with the values that defines its normative autonomy. For Georgia, this means not only the financial support, but also strengthening of institutional stability, the enhancement of government transparency and advancement of public accountability.

The European Union's normative engagement in Georgia operates on multiple level: on the one hand, it promotes the development of local democratic institutions and the empowerment of civil society and on the other hand it facilitates the institutional consolidation of legal and economic reforms. Consequently, the Global Gateway emerges not only merely a mechanism for infrastructural development, but also an instrument for political stability and value-based transformation.

Within the Global Gateway investments in education and healthcare sectors is aiming enhancing human capital, promoting knowledge transfer and ensuring social stability. As a result, the EU's normative objective is closely intertwined with its economic and infrastructural policies, creating a systematic equilibrium in which development, security and values become interdependent elements.

Thus, for Georgia, Global Gateway constitutes not only a source of economic benefit, but also a strategic platform, that strengthens the country's political agency, economic resilience and European integration. Investments in infrastructure, energy and digital development are synchronized with value-oriented framework, ultimately positioning Georgia as a model partner in the implementation of EU's global strategy.

"Trump's Road" and Georgia: Geopolitical and Economic Implications

Recent developments, particularly the agreement reached between Azerbaijan and Armenia under the mediation of U.S. President Donald Trump regarding the transfer of the so-called *Zangezur Corridor* - hereinafter referred to as *"Trump's Road for International*

Peace and Prosperity"-to the United States on a 99-year lease for operational management, are expected to introduce substantial adjustments to the Caucasian dimension of the *Global Gateway* strategy. Although it is premature to predict all details, several essential aspects deserve closer examination.**[Federal Register.2025]**.

Immediately following the announcement of the agreement, debates emerged within Georgian expert circles. The dominant tone of these discussions was marked by caution and scepticism rather than optimism. Many analysts emphasised that the new corridor represents a serious alternative route that may reduce Georgia's strategic transit importance and lead to potential losses in transport-related revenues. Conversely, some commentators argue that the international transport routes passing through Georgia and the proposed *Trump's Road* should be viewed as complementary rather than mutually exclusive.

In our assessment, these two perspectives need not contradict one another. In practice, the existing and forthcoming transit projects across the Caucasus may simultaneously assume both substitutive and complementary roles, depending on the specific nature of cargo, the economic objectives of cargo owners, and the evolving geopolitical context. This diversification of routes is likely to enhance regional cargo turnover, strengthen competition, improve service quality, and ultimately contribute to the broader economic advancement of the region.

However, when a country becomes the exclusive owner of a critical transit artery or another high-value asset, certain economic and institutional risks emerge - particularly in political environments where democratic institutions are fragile, judicial independence is uncertain, and economic populism prevails. In such cases, the abundance of unearned income from exclusive access to strategic assets can foster what scholars Hazem El Beblawi and Giacomo Luciani conceptualised as a *Rentier State* mentality**[Beblawi, Luciani. 1987].**

This phenomenon implies that instead of promoting economic diversification and institutional reform, easy and continuous revenue inflows may entrench inefficiency, reduce incentives for innovation, and reinforce authoritarian tendencies. Rentier dynamics thus risk deepening existing governance problems rather than resolving them, as unearned rents tend to obscure the shortcomings of populist economic policies and postpone necessary structural reforms.

In this regard, the launch of the *Trump's Road* may not entirely eliminate such vulnerabilities. On the contrary, the sharp increase in transit-related income could, under certain circumstances, encourage greater economic populism and political centralisation within all three South Caucasus countries.

Nonetheless, this scenario also presents a potential opportunity. The increased financial inflows could, if managed wisely, serve as a foundation for diversifying national economies, investing in human capital and innovation, and accelerating the adoption of renewable energy technologies. Whether these positive outcomes materialise will depend on the political will of regional leaders and the broader societal determination to pursue sustainable and inclusive development paths.

Ultimately, the *Trump's Road*- if implemented transparently and aligned with regional cooperation mechanisms - may contribute to enhancing the overall transport capacity of the Caucasus and promote a more interconnected, competitive, and economically resilient regional system. Its success will depend not merely on infrastructure construction but on governance quality, regional coordination, and the ability of the involved states to transform short-term transit advantages into long-term developmental gains.

CONCLUSIONS

For Georgia, the Global Gateway represents a critical strategic opportunity that simultaneously advances regional integration, economic development, infrastructural modernization, and the consolidation of normative and institutional frameworks. As a flagship initiative of the European Union, it offers not only transport and economic advantages but also reinforces the institutional capacities necessary for democratic governance, the rule of law, and transparent public administration. Through its multidimensional structure, the initiative situates Georgia within a broader geopolitical, infrastructural, and normative architecture that strengthens its position both regionally and globally.

The infrastructure component of the Global Gateway, encompassing roads, railway networks, logistical hubs, maritime ports, and energy systems, positions Georgia as a pivotal logistical node within major Eurasian transit routes. Enhanced connectivity between Europe and Asia increases the competitiveness of Georgian transit corridors and contributes to the expansion of domestic economic activity by supporting local enterprises and enabling their deeper integration into regional and international value chains. The infrastructural transformation therefore becomes not only a technical modernization effort but also a catalyst for long-term national development, fostering greater economic resilience and strategic relevance.

Complementing the physical infrastructure dimension is the initiative's economic and financial architecture, which ensures the sustainability and feasibility of large-scale projects. This includes mechanisms such as blended financing, public–private partnerships, credit instruments, and investment guarantees. By stimulating private sector participation and attracting diversified capital flows, the Global Gateway strengthens Georgia's long-term investment environment. Sustainable financing is especially crucial for a country where regional stability, fiscal resilience, and development prospects depend on continuous and predictable economic support.

Equally significant is the initiative's value-based and normative dimension. The European Union actively promotes principles related to democratic governance, human rights protection, transparency in public administration, and environmental sustainability. The adoption and institutionalization of these standards enhance Georgia's internal stability and reinforce the country's regulatory framework, contributing to a more predictable and credible institutional environment. This normative convergence not only strengthens Georgia's alignment with European governance models but also improves its international standing by demonstrating commitment to shared democratic values.

The Global Gateway should therefore be viewed not merely as a collection of technical or financial projects but as a strategic instrument for expanding the European Union's geopolitical presence. For Georgia, this translates into new opportunities to participate actively in regional political dynamics, economic initiatives, and transcontinental connectivity processes. By being embedded in the EU's connectivity vision, Georgia gains increased agency within international systems, enhancing its ability to shape regional development agendas.

Deriving from these dynamics, Georgia's strategic engagement with the Global Gateway requires the strengthening of institutional capacities to ensure effective project implementation, monitoring, and coordination. Enhancing administrative efficiency will support the timely realization of large-scale infrastructure initiatives and increase Georgia's credibility as a reliable partner. Furthermore, the integration of multimodal infrastructure - linking road, rail, maritime, and energy systems - should be prioritized to fully leverage the country's logistical potential. Developing digital logistics platforms and ensuring interoperability across sectors would significantly enhance the competitiveness of Georgian transit routes.

In parallel, the strengthening of the public-private partnership framework is essential to attract high-quality investments and ensure balanced risk-sharing. A more robust regulatory environment for PPPs would accelerate major infrastructure projects and stimulate private sector involvement. Aligning domestic legislation with EU normative standards, particularly in areas such as transparency, environmental safeguards, competition policy, and public governance, would further consolidate Georgia's institutional compatibility with European structures. This harmonization would also improve investor confidence and reinforce the sustainability of economic cooperation.

To safeguard the long-term feasibility of strategic projects, Georgia must diversify its financial instruments and explore blended financing models that reduce fiscal pressure while supporting large-scale investments. Collaboration with international development banks and European financial institutions will be critical in this regard. Additionally, enhanced regional diplomacy is essential for optimizing cross-border connectivity. Georgia's transit potential increases substantially when supported by a stable and cooperative regional environment, making diplomatic engagement a necessary complement to infrastructural development.

Ensuring that domestic enterprises benefit from the new infrastructure is also vital. Policies aimed at supporting small and medium-sized businesses, developing industrial zones, and promoting digital trade platforms would enable deeper national economic integration with emerging regional corridors. Strengthening environmental impact assessment systems and transparency mechanisms will align Georgia with EU requirements while increasing public trust and international legitimacy. Finally, adopting a clear strategic communication framework would help articulate Georgia's role as a reliable, democratic, and secure partner in European and Eurasian connectivity networks, further enhancing its geopolitical relevance.

At the same time, recent geopolitical shifts—including intensified competition over regional corridors, the emergence of alternative transit routes, and evolving security risks—highlight the fragility of Georgia's transit-dependent growth model. Initiatives such as the Middle Corridor, the Green Energy Corridor, and the proposed Trump's Road illustrate that Georgia faces both heightened opportunities and new competitive pressures. These dynamics underscore the necessity for Georgia to pursue a diversified and adaptive transit strategy: one that does not rely solely on its existing corridor advantages but proactively upgrades infrastructure, strengthens institutional capacity, and enhances multimodal competitiveness.

Ultimately, the Global Gateway initiative provides Georgia with a strategic path toward deeper integration into European and international infrastructural, economic, and normative landscapes. It enhances national resilience, strengthens security, supports sustainable economic growth, and expands the country's influence in global affairs. More than a series of infrastructural or economic projects, the Global Gateway constitutes a long-term, value-based developmental opportunity for Georgia—one that elevates its regional importance and reinforces its strategic role within the broader international system.

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THE LANGUAGE OF IMAGERY AS A COMPONENT OF THE PROFESSIONAL TRAINING OF FUTURE MATHEMATICS TEACHERS

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ABSTRACT

The article examines the concept of the «language of images» as an element of mathematical education, for the perception of abstract mathematical concepts in a visual format, facilitating their assimilation and understanding. The language of images is expressed through its syntax, semantics and pragmatics, as a basis for the formation of the visual subcompetence of the mathematics teacher as a component of information competence. The research addresses retrospective aspects of the use of visual aids in teaching mathematics, describes modern digital tools, their role in the development of critical thinking and their role in the development of the language of images in mathematics education. Special attention is also paid to the strategy of forming future teachers' visual subcompetence as an important component of their information competence, which is based on analysis, creation and interpretation of visual models. Recommendations for the integration of the language of images into pedagogical practice are proposed in order to increase the effectiveness of mathematics education.

Key words: visualization, visual subcompetence, mathematics education, language of images, teacher professional training, digital instruments

INTRODUCTION

In education, the concept of a visual image has long been a means of cognition and communication. Mathematics, as the science of abstract concepts, objects and relations, quite often requires visual embodiment and assimilation. As early as the 70s and 80s of the 20th century, teachers actively used technical teaching aids, such as slides and slide projectors, graph projectors with transparent films, on which mathematical objects and ways of solving problems were depicted with color markers. Codeprojectors, filmstrips and educational film fragments were also used, which made it possible to illustrate the dynamics of mathematical processes. To provide educational institutions with materials, there were even special

delivery points where teachers took tapes for film projectors or filmstrips for a certain period of time and returned them after use. The technologies mentioned provided visibility for learning, laid the foundation for the development of modern multimedia technologies, which have become an integral part of the educational process.

Today, the role of graph projectors has been taken over by interactive whiteboards, presentation programs, virtual laboratories and specialized digital environments such as GeoGebra, Desmos, Wolfram Alpha, Mathematica and others. These tools not only reproduce images, but also allow dynamic interaction with mathematical models, combining static visibility with interactive capabilities. The teacher's professional standard, enshrined in a number of documents, in particular in the Order of the Ministry of Education and Culture of Ukraine on the approval of the professional standard «Teacher of General Secondary Education Institution» [1], the State Standard of Specialized Secondary Education [2], in the instructional and methodological recommendations for teaching educational subjects [3], provides mastery of modern teaching methods, effective use of digital tools and integration of figurative presentations into the educational process. Thus, the educational process combines the experience of using visualization and modern digital technologies, meets the legislative requirements and professional standard of the teacher and ensures effective formation of students' competences in mathematics education.

Problem statement

Despite the rich potential of visual aids, their use in practice is often fragmentary, sometimes imposed, overloaded. In some educational institutions, visual materials are used only as auxiliary tools for illustrating individual topics and not as a system-forming component of the educational process. This creates a contradiction between the possibilities of figurative representations and their real embodiment in the study of mathematics. Therefore, the task of the research is to determine the content, structure and functions of the ”language of images” as a subcompetence in the professional activity of a mathematics teacher and to develop ways of its formation in the process of training future teachers.

Purpose of the research

The purpose of the research is the theoretical substantiation and disclosure of the content of the concept «language of images» in the context of mathematics education, the definition of its functions and components, as well as the search for ways to form future and current mathematics teachers' visual subcompetence. The research is designed to contribute to the systematization of knowledge about visual learning tools and their role in mathematics education.

Presentation of the main material

The question of visual thinking was raised in various areas of mathematics. Since antiquity, visual models have been used to prove theorems. For example, in Euclid's work «Elements» [4], theorems are accompanied by diagrams that act as a means of prof. Avigad's article «The Role of the Diagram in Euclid's Elements» [5] describes how diagrams provide relationship information and promote understanding. It is worth mentioning Plato, who in his writings interpreted geometric images as a way to understand the problem. Aristotle emphasized the importance of images in the process of forming abstract knowledge [6]. During the Renaissance, Leonardo da Vinci combined artistic and mathematical images, creating visual models of proportions, symmetry and perspective. Further development of visualization ideas can be traced in the writings of René Descartes, who introduced coordinate geometry by combining algebraic expressions with graphic constructions [7]. The theoretical foundations of figurative thinking were described by Clark and Paivio in their work on the theory of double coding [8]. The issue of improving mathematical education, in

particular the introduction of visual means for the development of figurative thinking, formation of professional teachers' readiness and integration of information technologies into the educational process, was reflected in the works of a number of Ukrainian scientists. A significant contribution to the development of this scientific problem was made by: L. Bilousova, N. Dehtiarieva, M. Drushliak, V. Vember, N. Zhyiteniova, T. Kolomiiets, P. Mulesa, V. Osadchiy, N. Ponomariova, O. Semenikhina , I. Chorna and others. These researches point to the importance of visualization as a component of teacher's professional competence and emphasize the need for a systematic approach to «language of images» formation in pedagogical practice.

In the context of researching the topic, the language of images is not only a set of illustrations or visual materials, it is also a system of signs and symbols that is a means of thinking, communication and self-expression, transforming abstract concepts in visual forms. Each image used in mathematics (e.g. a graph, diagram, geometric model) acts as a sign that carries a certain semantic load. This «language» allows to briefly submit information without losing content. Its effective use involves formation of a certain subcompetence, visual, which includes the ability not only to create images, but also to «read», analyze and use them effectively in the educational process. Mathematics is an abstract science, and visualization is a bridge between abstraction and a specific image.

Language of images in mathematics education is an effective form of visual media organization based on three key components, syntax, semantics, and pragmatics, which promotes not only knowledge transfer but also the development of students' cognitive and communication skills, allowing them to master complex mathematical concepts through intuitive forms. It, as a system of signs, ensures structuring, transmission and interpretation of information. «The image» in this context is a sign that encodes mathematical information and ensures its availability for further interpretation. For example, the graph of the function $y=f(x)$ is not just an image but a coded system that displays the relationship between variables, their properties and behavior.

Like any language, it has its own syntax, semantics and pragmatics.

The syntax of the «language of images» defines the rules for creating and combining visual elements. This includes standards for constructing graphs (coordinate axes, scale, notation), geometric shapes (points, segments, angles) or diagrams (columns, sectors). For example, a correct graph entry involves clearly marking axes, scales, and critical points, which ensures unambiguity of perception. Incorrect use of syntax, such as incorrect scale or lack of notation can lead to information distortion.

Semantics is responsible for the conceptual apparatus, the meaning of information that is transmitted by visual elements and their relationships. For example, the point of intersection of two graphs symbolizes the solution of a system of equations, and the slope of a straight line reflects the rate of change of quantity. Semantics provides a link between the image and the mathematical concept it represents. For example, in a histogram, the height of a column represents the frequency of a certain event, and in a geometric diagram, the angle between segments can indicate the property of orthogonality.

The pragmatics of the language of images determines the ways of its use in the educational process. It covers students' ability to analyze visual data, create their own models and apply them to problem solving, as well as teacher's ability to effectively use images to explain material and organize educational activities. For example, a teacher demonstrates a diagram, explains the properties of a function or a geometric figure, asks questions so that students draw their own conclusions.

The pragmatic aspect includes reading and interpreting graphs and charts, creating their own visualizations such as flowcharts or models, formulating conclusions based on visual data; and using digital platforms to create dynamic models.

One of the key points of future teacher professional training, in particular mathematics teachers, is formation of visual subcompetence as one of the components of information competence [12], which constitutes the basis of mastery of the language of images. This approach involves the ability to perform semantic compression of information, in other words, to present information in «compressed» form without losing semantic content, transforming mathematical concepts into visual representations. We single out key concepts, cut off the secondary and paraphrase the content for better understanding.

In the context of mathematics, this «compression» takes the form of a visual representation, where, for example, when graphing the function, emphasis is placed on critical points, interval growth or decline, and asymptotes. One of the successful interpretations of the monotony of the function can be an appeal to folk wisdom, for example: "The further into the forest, the more firewood" (literary translation from Ukrainian), «The further you go the worth it gets» (English equivalent).

Let's graph how the amount of firewood increases as you move into the forest. The horizontal axis of the graph in this interpretation corresponds to the forest road, and the vertical one reflects the amount of firewood that can be found on a certain kilometre of the road (see Figure 1).

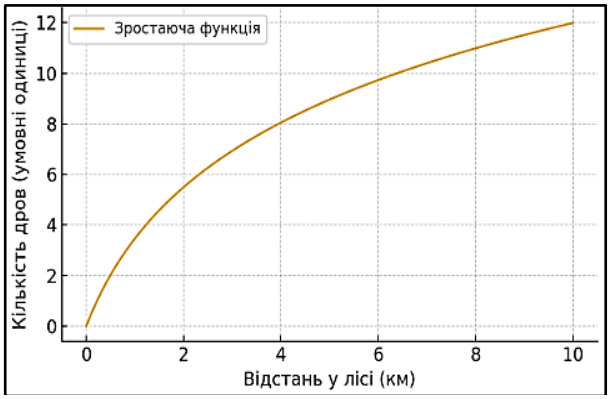

Figure 1. Graph of the growing function (« The further into the forest, the more firewood»)

Similarly, the proverb «You drive quieter – further will be» (literary translation from Ukrainian), "More haste, less speed" (English equivalent) can be given as an example of a decreasing function, where the lower the speed of movement, the longer the path can eventually be overcome (see Figure 2).

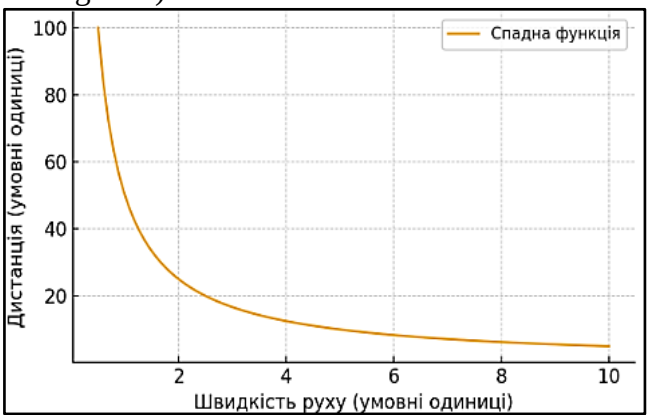

Figure 2. Declining function graph (« Quieter you go – further you will be»)

Such figurative explanations help students intuitively understand the idea of growing and declining functions, and graphs clearly emphasize these associations. This visualization is an example of semantic compression, transformation of an abstract notion of monotony into an intuitive image, sayings that can be described by mathematical dependence. Also, in the form of creative tasks, future mathematics teachers can be offered to independently

choose folk sayings and proverbs and display them in the form of graphs. For example, the expression «Above the measure a horse does not jump» (literary translation from Ukrainian) can be interpreted as an example of a bounded function (see Figure 3). If you depict the trajectory of a horse during jumps, then the height of such jumps, in full accordance with the content of the proverb, will be limited from above by a certain limit value (physiological capabilities of the animal, laws of physics, etc.). Such tasks activate creative thinking, develop ability to interpret abstract mathematical concepts in a clear and close form to students, develop visual subcompetence through folk creativity.

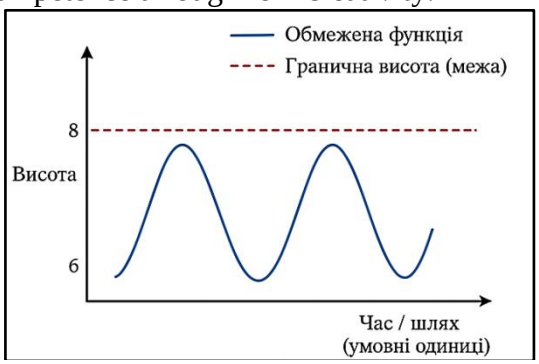

Figure 3. Bounded function graph («Higher than measure horse does not jump»)

Visual subcompetence, as a component of information competence, includes analytical skills (ability to decipher the meaning of graphs, schemes and diagrams), synthetic skills (creating correct visualizations to represent mathematical ideas), transformational skills (modifying images to solve problems or explain concepts), and communication skills (using images to justify conclusions or impart knowledge). Formation of visual subcompetence requires a systematic approach involving both theoretical familiarity with syntax and semantics of images and practical exercises to develop pragmatic skills.

In our opinion, formation of visual subcompetence allows us to present visual information as an active dialogue, where the student not only observes, but understands and interprets the content of what is presented.

Based on the analysis of pedagogical approaches, it is possible to single out a number of strategies for the formation of the language of images, namely:

- working with diagrams, schemes, graphs to identify relations and regularities;
- creating diagrams, drawings or interactive models to represent mathematical concepts;
- comparing textual explanation to corresponding image to form the relationship between a word and an image;
- applying figurative comparisons to explain abstract concepts, which helps activate semantic and visual memory;
- teaching students to explain diagrams or graphs, and how it is related in a mathematical context;
- use of multimedia presentations, digital tools to create dynamic models, which allows to experiment and change parameters in real time.

These strategies are aimed at ensuring that the «language of images» becomes not only a passive way of perceiving information, but a component of educational activity that promotes development of critical thinking and deepens understanding of mathematical concepts, develops ability to correctly understand mathematical content.

Structurally, the language of images can be presented in the form of a gradual accumulation, starting from the elementary level (points, lines, columns, figures, tables), later as a combinatorial level (combination of simple images into complex structures, diagrams, block diagrams, graphs, illustration of dependencies) and as an analytical level (simulation of processes, forecasting of results, search for solutions). Such a structure allows learners to

gradually move from simple visual elements to complex ones. In the process of learning, students gradually master the language of images.

An example of the use of image language would be a graph of the function y = x^2 , on which the vertex, axes of symmetry, points of intersection with axes, and intervals of rise/fall are clearly marked, making it easier to understand the properties of the parabola. Also, one of the classic examples of the use of image language in mathematics is a geometric scheme for proving the theorem on the sum of the angles of a triangle (see Figure 4). This method allows you to clearly demonstrate that the sum of the angles of any triangle is equal to 180°, presenting the proof to a clear visual construction.

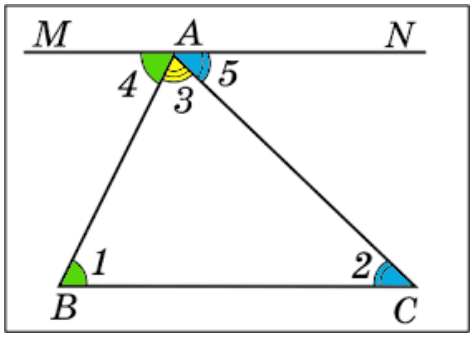

Figure 4 Geometric scheme for proving the theorem on the sum of the angles of a triangle

For the effective implementation of the language of images in mathematics education and formation of future mathematics teachers' visual subcompetence, we offer the following recommendations:

Syntax training. Enter standardized rules for constructing graphs, schemes and diagrams (for example, marking axes, choosing a scale). Provide examples of correct visualizations for learning syntactic norms.

Semantics development. Explain the meaning of visual elements through analogies (for example, a graph as a «map» behavior function). Conduct exercises to compare images with mathematical concepts.

Pragmatics training. Set tasks to create visualizations (for example, graphying a schedule for data sets or creating a block diagram for an algorithm). Use interactive tools, online services e.g. with dynamic models.

Visual subcompetence formation. Include modules on the development of skills in creating, analyzing and interpreting visual models in the educational programs of pedagogical universities. Organize practical sessions where future teachers create their own visualizations and explain their relationship to mathematical concepts or real-life examples [14]. Implement assessments that include creative tasks to analyze, create and interpret visualizations, as well as test the ability to explain practical, real life situations and one's own visual models.

Integration of digital tools. Teach future teachers to use modern platforms (GeoGebra, Desmos, Wolfram Alpha, etc.) to create interactive models. Develop skills in adapting digital tools to the needs of a specific lesson or task.

CONCLUSION

The language of images in mathematics education is a modern and powerful tool for structuring, transferring and assimilating knowledge through visual means. It is based on syntax, semantics and pragmatics, which ensure its functionality as a system of signs. Formation of visual subcompetence is a key to the effective use of this language, allowing transformation of abstract mathematical concepts into understandable images. Systematic

implementation of the concept of the language of images in the educational process, in particular through the use of digital tools and practical tasks, contributes to increasing the learning effectiveness, development of critical and creative thinking and formation of modeling skills.

In the professional training of future mathematics teachers, special attention should be paid to the development of information competence and its component of visual subcompetence through purposeful teaching of syntax, semantics and pragmatics of the language of images. The integration of modern digital tools and practical strategies, such as creation of interactive models and comparison of textual and visual representations, allows teachers to develop the skills necessary for the effective use of visualization in pedagogical practice. We plan to direct further research to the development of specific methods for assessing visual subcompetence and analyzing its impact on the quality of mathematics education.

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COMPARATIVE ANALYSIS OF ROTIFER COMMUNITIES IN NATURAL LAKES AND RESERVOIRS OF NORTH MACEDONIA

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ABSTRACT

Rotifers are widely recognized as effective bioindicators of freshwater ecosystems because of their sensitivity to environmental changes, rapid life cycles, and central role in aquatic food webs. In North Macedonia, natural lakes such as Ohrid, Prespa, and Dojran, alongside numerous artificial reservoirs, represent key aquatic habitats with contrasting ecological dynamics. Understanding differences in rotifer communities between natural and artificial systems is crucial for evaluating ecosystem health and the impacts of anthropogenic pressures. This study compares rotifer assemblages in natural lakes and reservoirs of North Macedonia, focusing on community structure, diversity, and responses to environmental drivers. The analysis is based on published studies and long-term monitoring programs. Results demonstrate higher diversity and stability in natural lakes, dominated by oligotrophic and mesotrophic taxa, while reservoirs exhibit lower species richness, stronger fluctuations, and dominance of opportunistic taxa associated with nutrient enrichment. These findings highlight the role of rotifers as indicators of hydrological and trophic stability, and emphasize the importance of continued ecological monitoring in the face of climate and land-use changes.

Keywords: rotifers, lakes, reservoirs, community structure, bioindicators, North Macedonia

1. INTRODUCTION

Rotifers represent a key component of freshwater plankton, contributing significantly to nutrient cycling and serving as an important food source for higher trophic levels(Gilbert 2022). Their rapid reproductive cycles and ecological sensitivity make them valuable indicators of environmental change (Ejsmont-Karabin et al. 2020a). Research in North Macedonia has shown that rotifer communities respond strongly to variations in trophic status, hydrodynamics, and anthropogenic pressures, making them useful for ecosystem assessment.

The country's freshwater network includes three ancient natural lakes (Ohrid, Prespa, and Dojran) and numerous reservoirs constructed primarily for hydropower, drinking water supply, and irrigation. These systems differ markedly in origin, age, hydrology, and nutrient dynamics, offering a natural contrast for assessing how environmental stability shapes plankton communities.

2. LITERATURE REVIEW

Previous investigations by Tasevska and collaborators (2008, 2012a, 2012b, 2015, 2017a, 2017b, 2019, 2024) provide comprehensive insight into rotifer diversity and structure across these contrasting habitats. This manuscript integrates these findings to elucidate how habitat origin, trophic state, and hydrological regime shape rotifer communities in Macedonian inland waters.

3. METHODS

This comparative analysis is based on a synthesis of existing published research and long-term monitoring data:

1. Published works by Tasevska and colleagues on zooplankton dynamics in:
    - Ancient lakes (Ohrid, Prespa): Characterized by stability, great age, and unique biodiversity (endemism). Lake Ohrid is notably oligotrophic (nutrient-scarce), while Lake Prespa shows signs of mesotrophy and ongoing eutrophication.
    - Shallow/Impacted lakes (Dojran): Highly eutrophic, reflecting significant anthropogenic and climatic pressures.
    - Reservoirs: Typically characterized by high hydrological fluctuations, rapid nutrient cycling, and high vulnerability to land-use impacts (e.g., Špilje, Konče 1, and Konče 3 reservoirs).
2. Long-term monitoring data from the Hydrobiological Institute – Ohrid (Guseška et al. 2012, 2014; Kostoski et al. 2024).
3. Secondary literature on trophic indicators and freshwater rotifer ecology (Sládeček 1983; Segers 2008;Estlander 2024).

Rotifer community characteristics were evaluated based on:

- Species richness and abundance.
- Dominant taxa and seasonal succession patterns.
- Functional feeding groups.
- Trophic state indicators.
- Environmental drivers including Total Nitrogen (TN), Total Phosphorus (TP), Secchi depth, and hydrological regime.

Comparisons were made between natural and artificial systems by trophic status (oligotrophic → eutrophic) and by hydrological stability (stable → regulated).

4. RESULTS

4.1. Comparative summary of rotifer assemblages

A comparative overview of the rotifer communities across the studied natural lakes and reservoirs is presented in Table 1, structured along the observed trophic gradient.

Table 1. The rotifer communities across the studied lakes

Habitat (Trophic Status)	Species Richness (Approx.)	Mean Abundance (Ind L^{-1})	Dominant Taxa	Ecological Signature
Lake Ohrid (Oligotrophic, Natural)	73 taxa (Tasevska 2019)	Low (5–10)	*Keratella cochlearis*, *Kellicottia longispina*	**High stability**, oligotrophic conditions, stenothermic species.
Lake Prespa (Mesotrophic/Eutrophic, Natural)	44 species (Tasevska et al. 2015)	Moderate/Variable	*Brachionus angularis*, *Trichocerca* spp.	Signs of **enrichment** and mesotrophic status, high littoral diversity.
Lake Dojran (Eutrophic, Natural/Shallow)	55 species (Tasevska et al. 2012)	High (> 120)	*Brachionus calyciflorus*, *B. plicatilis*, *Asplanchna priodonta*	**Eutrophic stress**, unstable dominance, fast-reproducing species.
Špilje Reservoir (Oligotrophic/Regulated)	10 taxa (Tasevska et al. 2017)	Low (mean 2.9 ± 4.1)	*Kellicottia longispina* (47%)	**Lower diversity** than natural counterpart, but still reflects low nutrients.
Konče Reservoirs (Eutrophic/Regulated)	13 taxa (Tasevska et al. 2017)	Very High (mean 50 ± 7.8)	*Brachionus falcatus*, *B. angularis*, *Hexarthra mira*	**High abundance**, extreme variability, dominance of opportunistic taxa.

4.2. Natural lakes

Natural lakes exhibited higher species richness and taxonomic diversity overall, with stable seasonal succession patterns.

- Lake Ohrid showed particularly persistent oligotrophic signals (Tasevska 2019). The low mean abundance (5–10 ind L^{-1}) reflects oligotrophic conditions and strong predation control by copepods and cladocerans. Diéguez et al. (2002) and Conde-Porcuna and Declerck (1998) have shown that predation by copepods can suppress rotifer populations, while experimental and field studies indicate that large filter-feeding cladocerans outcompete and reduce rotifer densities (MacIsaac and Gilbert 1989; Arcifa et al. 2020). The community is characterized by a balanced mix of microphagous filter feeders and raptorial species, indicating stable food-web interactions (Obertegger and Manca 2011; Horppila 2019).
- Lake Prespa, characterized by mesotrophic to eutrophic tendencies, displayed higher seasonal variability, linked to agricultural runoff and water-level fluctuations, with periodic dominance of *Brachionus angularis* and *Trichocerca* spp. during summer (Tasevska et al. 2015). This indicates a mesotrophic regime with clear signs of enrichment due to catchment eutrophication.
- Lake Dojran, the most eutrophic, showed the highest total abundance but also the greatest seasonal fluctuations. Elevated phosphorus levels (TP > 60 µg L^{-1}) promote opportunistic fast-reproducing species species like *Brachionus calyciflorus* (Tasevska et al. 2012a).

4.3. Reservoirs

Reservoirs were characterized by lower species richness compared to natural lakes and higher total abundance fluctuations. The communities were generally dominated by opportunistic taxa (Tasevska et al. 2017).

- Eutrophic reservoirs (Konče 1 and 3) recorded very high mean densities (up to 50,049 ind L^{-1}), with dominant species like *Brachionus falcatus* and *B. angularis*. This pattern is driven by nutrient-rich and hydrological instability, favouring species with fast reproductive rates (r-strategists) (Galir Balkić et al. 2018).
- Even oligotrophic reservoirs (Špilje), while having low abundance, showed significantly lower diversity (only 10 taxa recorded), emphasizing the impact of hydrological regulation on diversity, regardless of nutrient concentration.

5. DISCUSSION

The observed patterns underline fundamental ecological differences between natural lakes and reservoirs in North Macedonia. Long-term stability in natural lakes supports diverse and structured rotifer assemblages (Shurin et al. 2010). Reservoirs, in contrast, are driven by external nutrient pulses and artificial water level changes that favour opportunistic and r-strategist taxa (Seong-Ki et al. 2020).

Rotifer diversity and community structure in North Macedonian waters mirror a clear ecological gradient:

- Trophic transition: The gradient moves from oligotrophic stability (Ohrid, Špilje) → to mesotrophic fluctuation (Prespa) → to eutrophic instability (Dojran, Konče reservoirs).
- Species shift: Species composition transitions from cold-adapted and slow-reproducing (e.g., *Kellicottia*, *Keratella*) to warm-tolerant, opportunistic taxa (e.g., *Brachionus*, *Filinia*).
- Bioindicator confirmation: These findings align with the global pattern where *Brachionus* and *Hexarthra* serve as indicators of eutrophic, unstable habitats. Studies have shown that *Brachionus* frequently dominates rotifer assemblages in eutrophic or human-impacted waters, while shifts in nutrient loading and trophic state are often mirrored by changes in rotifer community composition, with opportunistic taxa flourishing under disturbed conditions (e.g. Kim et al. 2020; Ejsmont-Karabin et al. 2020b; Phan et al. 2021; Kuczyńska-Kippen et al. 2025), whereas *Kellicottia* and *Keratella* reflect oligotrophic stability. Species such as *Kellicottia longispina* and *Keratella* spp. are frequently associated with oligotrophic, stable lake conditions and constitute dominant microphagous components of low-productivity plankton communities (Tasevska 2017b; Wærvågen and Andersen 2017). Reservoirs, despite sometimes having comparable nutrient levels to natural lakes, are more affected by hydrological regulation, short retention times, and frequent mixing, all of which intensify community instability and suppress diversity (Gabaldón et al. 2017; Seong-Ki et al. 2020; Tomljanović et al. 2025; Li et al. 2025).

This pattern demonstrates how rotifers integrate physical and chemical signals of ecosystem change, functioning as a biological "mirror" of freshwater health. The Macedonian data thus fit broader global findings that rotifer assemblage metrics can serve as sensitive indicators of trophic evolution and anthropogenic disturbance.

Future research should focus on:

- The impacts of climate-driven hydrological changes on Prespa and Dojran Lakes.
- The effects of land-use intensification in reservoir catchments.

- Assessing the success of restoration efforts and controlled nutrient management strategies.

6. CONCLUSION

Rotifer communities in North Macedonia show distinct biogeographical and ecological responses shaped by habitat origin, stability, and nutrient dynamics. Natural lakes support stable, diverse communities adapted to long-established conditions, whereas reservoirs host more variable and opportunistic assemblages. Rotifers therefore represent a valuable tool for assessing trophic state and disturbance, supporting freshwater management and conservation planning in the region.

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DISINFORMATION AND DIGITAL TRANSFORMATION: IMPLICATIONS FOR THE EUROPEAN INTEGRATION OF NORTH MACEDONIA

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ABSTRACT

Introduction: *This paper explores the dynamic relationship between digital transformation and disinformation, focusing on their implications for the European integration of North Macedonia. The study addresses the increased presence of disinformation, low levels of media literacy, and challenges in aligning national digital policies with European standards.*
Methods: *A combined theoretical and empirical approach is applied. The analysis highlights the European regulatory framework, with emphasis on the Digital Services Act and Digital Markets Act. Empirical data are collected through media content analysis, surveys, and semi-structured interviews with citizens and experts.*
Results: *Findings are expected to show that disinformation, especially as part of hybrid warfare, has significant influence on citizens' perceptions. Effective digital transformation and alignment with European regulations reduce institutional and societal vulnerability. Media literacy emerges as a central factor of resilience.*
Discussion: *The study confirms that disinformation erodes confidence in EU integration, whereas digital transformation and regulatory harmonization enhance resilience. Media literacy proves essential, though limitations remain. Future research should extend to regional comparisons and the role of algorithms in amplifying disinformation.*

Keywords: Digital transformation, disinformation, European integration, Digital Services Act, media literacy, hybrid threats

1. INTRODUCTION

The rapid expansion of digital technologies has fundamentally reshaped the way individuals access and interact with information, positioning digital transformation as a key element of contemporary governance. While digital innovations enhance transparency, efficiency, and citizen engagement, they simultaneously expose societies to an increased volume of harmful content, including misinformation and disinformation amplified through fast-growing online ecosystems. These dynamics create a dual landscape—one defined by technological advancement, and another marked by new risks to public trust and democratic resilience.

In the context of the enlargement of the European Union (EU), digital governance has become strategically important, influencing both democratic consolidation and security. Candidate countries are expected to align their regulatory frameworks and digital capacities with EU standards. North Macedonia faces a particularly complex environment where efforts for digital modernization intertwine with political polarization, socio-economic challenges, and operations of external influence. Despite progress in digital public services and institutional interoperability, vulnerabilities in information integrity and media literacy remain significant.

Disinformation is deeply rooted in the national information sphere, driven by domestic political actors, foreign influence, and opportunistic digital manipulation. Narratives targeting the EU and its policies are among the most widespread, aiming to undermine public trust in institutions and decrease support for North Macedonia's Euro-Atlantic integration. Limited media literacy further increases citizens' susceptibility to manipulation, creating a feedback loop in which disinformation erodes trust, and low trust amplifies the effect of disinformation.

These conditions highlight the need to strengthen societal resilience by combining institutional digital capacity with enhanced public awareness and critical thinking. This study examines the interconnection between digital transformation, disinformation, and public perceptions of EU integration. It recognizes both the opportunities offered by digital governance and the threats posed by information manipulation in shaping political attitudes.

The research aims to explore how disinformation influences citizens' attitudes toward European integration and to assess the role of digital transformation and media literacy in mitigating such influences. The central research question investigates how the processes of digital transformation and the dynamics of disinformation affect public trust in North Macedonia's EU accession. The additional questions relate to:

1. the key actors and narratives driving EU-related disinformation;
2. the extent to which digital transformation enhances institutional and societal resilience; and
3. how media literacy shapes citizens' vulnerability to false content.

By integrating theoretical insights with empirical evidence, the study contributes to current academic and policy discussions on digital governance, information security, and Europeanization. Its findings aim to support national efforts to align digital policies with EU standards and to strengthen societal commitment to democratic integration.

2. Literature Review / Theoretical Framework

2.1. Digital Transformation: Definitions, Trends, and Public Sector Reforms

Digital transformation represents the integration of advanced digital technologies into societal and institutional processes, leading to changes in organizational structures, culture, and the way public services are delivered (Mergel et al., 2019; Goldkuhl, 2011). It is not limited solely to technological adoption but implies improving efficiency, transparency, and accountability, as well as greater citizen involvement in governance processes (Bannister & Connolly, 2020).

In the public sector, digital transformation is most commonly realized through the development of e-government, which offers faster and more accessible services, reduced bureaucracy, and the limitation of corrupt practices (United Nations, 2022; World Bank, 2021). E-services such as digital identity, electronic submission of documents, or online payments enable the administration to be more productive and more user-oriented (European Commission, 2020).

Contemporary trends shift the transformation from basic digitalization toward intelligent and proactive governance. Technologies such as artificial intelligence, data analytics, automation, and the Internet of Things create a foundation for personalized and predictive public services (Criado & Gil-García, 2019; Lindgren & van Veenstra, 2018). Open data platforms strengthen transparency and encourage collaboration between the public sector and civil society (European Commission, 2022).

Digitalization simultaneously opens significant risks related to cybersecurity, data misuse, and vulnerability of critical infrastructure. Therefore, national digital strategies increasingly focus on resilience and the responsible use of innovations (World Bank, 2021). In the European context, the regulatory frameworks DSA and DMA set standards for transparency, security, and platform accountability, which are also important for candidate countries (European Commission, 2023).

Although digital transformation has strong developmental potential, it can deepen the digital divide, which manifests as differences in access, skills, and the use of digital tools (Van Dijk, 2019). This divide is pronounced between urban and rural areas, generations, and economic groups, especially in transitional countries. Limited access to digital services reduces trust in institutions and increases citizens' susceptibility to manipulation and disinformation (Bannister & Connolly, 2020).

For many countries in transition, such as North Macedonia, the digital divide persists due to socio-economic inequalities, limited investment in digital education, and insufficient workforce capacity. Vulnerable groups, including older people, low-income households, and communities in remote areas, may remain excluded from digital progress. This exclusion is particularly problematic in the public sector, where digital public services risk deepening inequality if alternative access channels are not maintained.

Therefore, successful digital reforms must be inclusive and combine technological advancement with education, infrastructural investments, and protection from cyber risks. Only in this way can digital transformation contribute to democratic stability, equal access, and increased public trust.

2.2 Disinformation and Hybrid Threats

Disinformation represents deliberately constructed and disseminated inaccurate information with the aim to deceive, mislead, or psychologically influence the audience and to achieve political, ideological, or economic influence over the public (Wardle &

Derakhshan, 2017). Unlike misinformation, which results from unintentional mistakes, disinformation is characterized by a clear strategic intention and often constitutes an integral part of broader hybrid warfare operations.

In contemporary digital ecosystems, disinformation exploits the speed, scale, and algorithmic logic of social networks, enabling the rapid circulation of manipulative messages, especially in environments with low trust in institutions and limited media literacy (Bennett & Livingston, 2018). It thrives in contexts characterized by high social polarization, limited institutional trust, and low levels of media literacy—conditions particularly present in transitional democracies (Tucker et al., 2018).

The concept of hybrid warfare describes a strategic approach that combines conventional and unconventional means to achieve political and geopolitical goals without a formal declaration of conflict. At its core, hybrid warfare operates in the "grey zone" between peace and open armed confrontation, using political, informational, economic, cyber, and cultural instruments to destabilize the opponent (Hoffman, 2007; Lind, 1989; Nemeth, 2002).

The Russian doctrine describes this approach as "information confrontation," where psychological operations, digital attacks, and media interventions are combined with traditional instruments of power (Gerasimov, 2013; Giles, 2016). Similarly, Chinese concepts of the "three wars", psychological, media, and legal, indicate strategies of influence without direct confrontation (Chekinov & Bogdanov, 2013).

From a Western perspective, hybrid warfare is viewed as a synergistic combination of military and non-military means, including propaganda, cyber operations, political influence, and economic pressure (Hoffman, 2007). Examples such as the actions of Hezbollah in the Middle East illustrate the capabilities of non-state actors to employ hybrid tactics (Krieg & Rickli, 2019).

In the context of North Macedonia and the wider Western Balkans, hybrid warfare most often manifests through disinformation campaigns, cultural-religious influence, political mediation, and economic pressures with the aim of weakening pro-European orientations and destabilizing social cohesion (Galeotti, 2016; Raichev, 2023). Therefore, this study uses the term "hybrid warfare" instead of "hybrid threats," because the concept of "threat" describes a potential or latent risk, while "warfare" indicates an active, intentional, and coordinated operation of influence. The analyzed examples in the Macedonian media and digital space fit more clearly within a model of hybrid warfare than within the more moderate concept of hybrid threats.

The structural characteristics of digital platforms additionally facilitate the spread of hybrid operations. Algorithms prioritize content that generates strong engagement, regardless of accuracy, creating echo chambers where false information can circulate unchallenged (Pariser, 2011; Bakshy et al., 2015). The rise of deepfake videos, altered historical narratives, and coordinated troll networks further complicates fact-checking (Chesney & Citron, 2019). New technologies advance rapidly, making disinformation tactics increasingly difficult to detect and regulate (Bradshaw & Howard, 2019).

Research shows that disinformation affects public perception through several mechanisms (Lewandowsky et al., 2017):

- agenda-setting and narrative shaping;
-emotional manipulation through fear, anger, and identity-based messages;
- delegitimization of institutions, especially in electoral contexts (Norris & Inglehart, 2019);
- creating uncertainty and confusion that weakens societal resilience (Paul & Matthews, 2016).

North Macedonia's vulnerability to such operations is intensified by the fragmented media landscape and the high dependence on digital platforms as primary sources of information. Studies show that a significant portion of online content related to European

integration contains polarizing or misleading narratives (European Commission, 2022). The infodemic spread of contradictory information reduces the public's ability to distinguish credible sources from manipulative ones (WHO, 2020), and vulnerable groups,especially young people and individuals with lower levels of education, are disproportionately exposed (Guess et al., 2019).

Traditional media regulation faces difficulties in monitoring decentralized and encrypted digital communication spaces (Kello, 2017). Although fact-checking initiatives have expanded, they often have limited resources and insufficient reach compared to the viral spread of false content (Graves & Anderson, 2020). Responding to disinformation requires careful balancing to avoid risks of excessive censorship, political misuse, or undermining democratic standards and media pluralism (Roberts, 2019).

Experts clearly indicate that disinformation and hybrid operations represent central security challenges in the digital era (Hoffman, 2007; Giles, 2016).

Their capacity to undermine democratic legitimacy is amplified in contexts where digital transformation progresses faster than protective institutional, legal, and educational mechanisms.

2.3 Resilience and Media Literacy as Mitigating Factors

Resilience, in the context of information ecosystems and societal security, refers to the capacity of individuals, institutions, and communities to resist, adapt to, and recover from manipulations or disruptions caused by disinformation and hybrid threats (Pamment, 2020; NATO StratCom COE, 2020). With the accelerated digital transformation and the emergence of new risks, resilience becomes a fundamental requirement for protecting democratic processes, maintaining trust in governance, and ensuring informed civic participation (Van Dijck & Poell, 2018). A resilient society does not avoid exposure to harmful information but possesses the abilities and structural mechanisms for its timely recognition, challenge, and limitation (Ulmer, Sellnow & Seeger, 2022).

Resilience in information environments is multidimensional. Institutional resilience refers to the ability of public institutions, regulators, and security agencies to detect and respond in a timely manner to manipulative information (OECD, 2024). This requires modernized legal frameworks, cross-sector coordination, and proactive digital governance policies, such as the EU standards outlined in the DSA and DMA (European Commission, 2022). Increased transparency, platform accountability, and strengthened cybersecurity reduce institutional vulnerability and contribute to trust in the digital public sphere (Roberts, 2019).

Technological resilience implies the development of systems and tools for identifying and limiting disinformation (Helberger, 2020). This includes investments in artificial intelligence for content verification, secure digital identity solutions, and interoperable systems that enable secure communication in public networks (Floridi, 2018). Innovative responses from technological companies, civil society, and academia play a significant role in protecting against coordinated manipulative campaigns (Bradshaw & Howard, 2019). Societal resilience is the most critical layer, as citizens are the direct target of disinformation.

A key element is media literacy, defined as the ability to access, analyze, evaluate, and create information across different media formats (Pamment, 2020). Media literacy enables citizens to recognize manipulations, verify sources, and participate responsibly in public discourse (Koltay, 2011). In societies with information overload, media literacy becomes both an educational and a security necessity (Stoilova et al., 2020).

In North Macedonia, media literacy is gradually being integrated into national strategies, but it remains unevenly developed (MIM, 2022). Younger citizens, who primarily

receive information through social networks, often lack structured knowledge of critical thinking and digital responsibility (Tandoc et al., 2018). Older generations, meanwhile, face difficulties in evaluating digital content, creating intergenerational differences in vulnerability to disinformation (Olphert, and Damodaran, 2013) and influencing political perceptions and social cohesion (Groshek & Koc-Michalska, 2017).

Research shows a strong correlation between media literacy and resilience: citizens with higher critical digital skills have lower susceptibility to false narratives, higher trust in institutional sources, and greater support for democratic reforms and European integration (Jones-Jang et al., 2021; Vraga & Tully, 2021). Therefore, improving media literacy not only limits the spread of disinformation but also strengthens public stability and the strategic orientation of the state. Educational programs, public campaigns, and fact-checking platforms represent key elements in creating informed and resilient communities (Graves, 2018).

Despite progress, challenges remain. Efforts to build critical digital skills often lack sustainable funding and systematic integration into curricula (Frau-Meigs et al., 2017), and the shortage of trained educators limits effectiveness (Bulger, 2018). Furthermore, countermeasures against disinformation must balance protection with freedom of expression to avoid censorship or political misuse (Roberts, 2019).

For sustainable resilience-building, states must adopt a holistic approach that integrates institutional capacities, technological solutions, and civic competencies into a single system (OECD, 2024). In the case of North Macedonia, alignment with European standards for digital governance represents a critical path toward strengthening systemic resilience and advancing the process of European integration (European Commission, 2022).

3. The Context of European Policy: The Digital Services Act and the Digital Markets Act

The European Union has established a comprehensive framework for digital governance aimed at improving accountability, competition, and consumer protection across the entire online ecosystem (European Commission, 2020; 2022). Two central regulations, the Digital Services Act (DSA) and the Digital Markets Act (DMA), represent a significant step toward strengthening digital rights and addressing the risks posed by powerful online platforms (European Parliament & Council of the EU, 2022a; 2022b). Together, these acts define the obligations of digital intermediaries, ensuring that online spaces remain safe, secure, and competitive, while at the same time supporting the EU's democratic values.

3.1 Digital Services Act: Transparency, Safety, and Platform Accountability

The Digital Services Act introduces a new set of standards that regulate the removal of illegal content, transparency in content moderation, and the empowerment of users (European Commission, 2023a). Its implementation requires platforms to distinguish between illegal and harmful content while at the same time protecting freedom of expression (Keller & Leerssen, 2020).

The DSA places particular responsibility on very large online platforms (VLOPs), which serve as primary channels for the distribution of news and information. These platforms must conduct risk assessments, monitor algorithmic impacts, and cooperate with independent auditors to prevent the spread of harmful digital behavior (European Commission, 2023b).

Combating disinformation represents a core objective of the DSA.

The regulation requires mechanisms that:

- ensure the traceability of digital advertisements,

- reduce the algorithmic amplification of harmful narratives, and
- facilitate improved cooperation with trusted fact-checking entities (European Commission, 2022b; NATO StratCom COE, 2021).

For EU candidate countries, such as North Macedonia, alignment with these standards is not only a formal requirement but also a critical tool for improving information security and democratic resilience (Tóth & Judit, 2022).

3.2 Digital Markets Act: Ensuring Fair Competition and Reducing Market Dominance

The Digital Markets Act (DMA) complements the Digital Services Act (DSA) by targeting the structural imbalances of the digital market and regulating the behavior of dominant technology companies. These companies, defined as "gatekeepers," control key digital infrastructures such as app stores, search engines, and social networks, which enables them to exert significant influence over the online ecosystem (European Commission, 2020). Previous analyses show that such market power often leads to self-preferencing, data misuse, and restrictions on competition, problems that the DMA aims to address (Crémer, de Montjoye & Schweitzer, 2019).

The DMA aims to restrict market practices that reduce consumer choice and hinder competition, such as algorithms for self-preferencing, bundling of exclusive services, or the accumulation and monopolization of data (European Commission, 2020). By establishing obligations for interoperability, transparency, and fair access to data, the regulation creates equitable conditions for business operations in the digital environment (Martensand Zhao, 2021).

By preventing monopolistic behavior and encouraging fair competition, the DMA supports a diverse and innovative digital market that benefits both citizens and small and medium-sized enterprises. This is particularly relevant for the Western Balkans region, where digital entrepreneurship and local innovation depend on fair access to European digital markets and on stable competitive conditions (OECD, 2024).

3.3 North Macedonia's Alignment with EU Digital Governance

North Macedonia has shown commitment to harmonizing its national legislation with the European digital agenda, however, progress is uneven. Policy initiatives, such as the National Cybersecurity Strategy, the creation of e-government portals, and the development of digital identity, signal significant steps towards modernization. However, several institutional and infrastructural gaps remain:

EU Requirement	**Current Status in North Macedonia**	**Key Challenges**
Platform accountability (DSA)	Partial adoption through media regulation updates	Limited platform oversight capacity
Transparency and content governance	Growing cooperation with fact-checkers and regulators	Lack of reliable monitoring systems
Fair digital market competition (DMA)	Legislative alignment underway	Slow adaptation for local SMEs
Cybersecurity standards	National strategies updated	Funding and workforce shortages

Figure. 1

Foreign influence and domestic political fragmentation continue to complicate the effective implementation of digital reforms. Moreover, the state's ability to counter disinformation campaigns remains constrained by insufficient coordination among public

institutions, regulators, and civil society organizations. Although legislative alignment is strengthening, practical enforcement remains the primary barrier.

3.4 Toward a European-Integrated Digital Ecosystem

Alignment with the DSA and DMA holds transformative potential for North Macedonia, particularly through:

- improved digital economy competitiveness,
- enhanced transparency in the information environment,
- reduced vulnerability to hybrid threats, and
- strengthened public trust in democratic institutions.

Effective implementation will require coordinated efforts in capacity building, cross-border cooperation, and long-term policy investment. Strengthening digital literacy and cybersecurity must accompany regulatory reform to ensure that legal compliance translates into real-world societal protection.

In conclusion, the European regulatory framework provides a critical roadmap for digital transformation in North Macedonia. By adopting and enforcing DSA and DMA principles, the country can enhance democratic resilience while advancing toward EU membership. The alignment process thus represents both a compliance obligation and a strategic opportunity for safeguarding digital sovereignty and promoting European values.

4. Methodology

This study applies a mixed-method research design to examine the relationship between digital transformation, disinformation, and public perceptions of EU integration in North Macedonia. The combination of quantitative and qualitative techniques enables a multidimensional understanding of how digital information environments influence societal attitudes and democratic resilience. Data were collected through analytical documents, media content, anonymous questionnaires, and semi-structured expert interviews. Out of 850 distributed surveys across different regions of North Macedonia, 302 responses were obtained, with participants representing diverse demographic profiles. A total of 130 individuals from academic institutions, journalism, public administration, and political actors were invited, but only 20 agreed to be interviewed on the topic. Additionally, open-source databases and the digital resources were consulted, without the use of sensitive or classified material.

The methodological framework integrates several complementary research approaches. Case study analysis was used to observe selected political events and foreign policy processes, offering insight into mechanisms of influence on North Macedonia. Qualitative analysis of expert interviews and survey responses made it possible to identify perceptions regarding the role of external actors and the mediation carried out by domestic political elites. Comparative analysis served to contrast national strategies with EU-level strategies and to assess divergences affecting institutional stability. Content analysis provided a systematic examination of official documents, strategic reports, international publications, and media sources, facilitating objective tracking of narratives and channels of influence. Descriptive and analytic-synthetic reasoning supported the interpretation and integration of empirical and theoretical insights. Long-term observation and monitoring of political developments, media discourse, and diplomatic activity supplied updated contextual information and a nuanced understanding of how legislative reforms, public statements, and international reactions shape the broader environment.

Through this combination of methods, the study offers a layered and coherent analytical perspective on how external influences intertwine with domestic political dynamics and how political actors in North Macedonia interpret, adapt, or instrumentalize these influences within national decision-making processes.

4.1. Empirical Findings: Case of North Macedonia

The empirical analysis provides valuable insight into the digital information environment in North Macedonia, particularly in light of the European Union's Digital Services Act (DSA), which emphasizes transparency, accountability, and systemic risk management within the online information ecosystem. The findings reveal structural patterns in how citizens consume international news, the extent of cross-border media influence, and the public's ability to identify disinformation. These are critical elements for assessing national preparedness for implementing DSA standards.

International news was selected as an analytical category because foreign political and media narratives represent a main channel through which hybrid influences are carried out in North Macedonia. Research by the EU, NATO StratCom COE, and domestic fact-checking organizations shows that disinformation campaigns most frequently relate to international politics, geopolitical issues, and cross-border events, rather than to local news. Therefore, exposure to international news represents a more useful indicator for assessing the population's vulnerability to hybrid operations.

4.1.1 Frequency of International News Consumption and Exposure to Digital Media

The survey results show that the majority of respondents (58%) follow news or international news daily, either several times a day or at least once a day, which indicates a high level of exposure to global information flows.

However, the depth and quality of engagement vary significantly across demographic groups.Although gender differences are minimal, age and education emerge as strong differentiating factors: older respondents (56–65) show lower engagement, with half of them reporting that they rarely consume international news, while younger and more educated respondents demonstrate higher levels of information consumption. This generational and educational divide reflects inequalities in digital literacy and media habits, which can directly influence resilience to online disinformation.

Geographical differences are also relevant. Respondents from urban areas tend to consume more news (37.5% several times a day), while those in rural areas report more limited exposure (38.5% only a few times per week). Such data suggest that digital access and infrastructure, as defined by DSA principles of equal access to online information, remain uneven across the country.

Ethnic differences further highlight patterns of selective exposure: Macedonian respondents (57.6%) are more frequent consumers of international news compared to respondents from other ethnic communities (55.5%), among whom nearly half acknowledge that they follow global news only occasionally. These results underscore a fragmented information landscape, where access to and trust in international media sources may vary along socio-cultural lines.

When it comes to gathering information about international relations and North Macedonia's global position, respondents rely on a variety of sources. Most use media outlets (32.67%) and social networks (23.76%), indicating a significant influence of digital platforms. Scientific and professional literature also plays an important role, but other unspecified sources (12.87%) and personal experience (8.91%) are mentioned as well,

pointing to a mix of informal and official sources in shaping perceptions. They rely least on official government statements (4.95%), which suggests a degree of skepticism or a preference for independent sources of information. Younger demographic groups rely more heavily on social networks for information compared to older respondents.

Regarding this question, there are no major differences in the opinions of the interviewed experts.

4.1.2 Influence of Cross-Border Media on the Macedonian Media Space

A key dimension relevant to the DSA's cross-border information regulation is the perceived influence of foreign digital content.

More than 70% of respondents believe that online content originating from Serbian media significantly influences both domestic news portals and public opinion in North Macedonia. This perception of influence remains consistent across gender, age, and place of residence, although it is slightly higher among women (75%) and urban respondents (71.6%). These findings reflect the regional interdependence of media ecosystems, where digital platforms transcend borders without adequate regulatory mechanisms. In the absence of strong domestic enforcement aligned with DSA obligations for very large online platforms (VLOPs) and media transparency, such external content can shape public narratives, spread bias, and potentially amplify disinformation (Tóth & Judit, 2022).

Education again emerges as a differentiating factor. Respondents with postgraduate qualifications (second cycle and above) show greater awareness of the influence of foreign media but are also more cautious in forming judgments (up to 44% expressing neutrality). This academic restraint suggests recognition of the complexity of hybrid information flows and an understanding that foreign content may influence not only information availability but also public trust in national media.

Most experts agree that disinformation is present but mainly originates from abroad and its influence is secondary, primarily affecting the country of origin. In this regard, they believe that domestic challenges such as corruption and political manipulation through fake news are more deeply rooted.

4.1.3 Public Awareness and Ability to Recognize Disinformation

Respondents were asked, "Does the public in North Macedonia know how to recognize disinformation and fake news?" to which 62.37% disagreed or strongly disagreed, revealing a significant gap in media literacy and critical information skills. Although divided, the experts also believe that the majority of the population, regardless of demographics, accepts unverified information as credible.

This aligns with the DSA's risk assessment obligations, which require member states and platforms to address systemic risks such as disinformation, manipulation, and the erosion of civic trust.

The lack of ability to recognize credible sources was consistent across all genders and age groups, with more than 60% in each demographic category acknowledging difficulties in identifying false information. This indicates low resilience to manipulation and hybrid interference, especially in the digital sphere where algorithmic amplification and cross-border circulation of content are common (European Parliament & Council of the EU, 2022a).

Interestingly, respondents from rural areas showed greater confidence (53.85%) in their ability to recognize disinformation compared to respondents from urban areas (25%), which likely reflects overconfidence rather than actual skill. Educational differences confirm this pattern: individuals with higher levels of education (over 65%) were more likely to

acknowledge the challenge, while those with lower levels of education often underestimated the complexity of identifying disinformation.

Ethnic analysis reveals similar results—two-thirds of respondents from both Macedonian and non-Macedonian communities acknowledge that the public struggles to identify fake news. This widespread perception underscores the national vulnerability to coordinated disinformation campaigns, highlighting the urgent need for comprehensive digital literacy programs (Helberger, 2020).

It is important to note that both respondents and experts agree that politicians in North Macedonia produce fake news in order to achieve political advantage.

4.2. Implications in the Context of the Digital Services Act

The findings indicate that North Macedonia's information environment mirrors many of the systemic risks that the DSA seeks to address, including algorithmic amplification of foreign content, lack of media transparency, and low user awareness of online manipulations.

In this context, the implementation of DSA-inspired standards could enhance national resilience through (European Parliament & Council of the EU, 2022a):

- **Transparency obligations for online platforms**, requiring them to disclose content sources, ownership, and moderation practices.
- **Mechanisms for countering disinformation**, such as verified media registries and fact- checking partnerships.

Table 1. Correlation Analysis of Key Variables Related to News Consumption and

Variables	**Frequency of News Consumption**	**Age**	**Gender**	**Education**	**Place of Residence**	**Ethnic Affiliation**	**Influence of Internet/ Serbian Media**	**Abilityto Recognize Disinformation**
Frequency of News Consumption	1.00	**0.62**	-0.05	**0.48**	**0.37**	**0.29**	0.12	0.21
Age	-0.62	1.00	0.03	**-0.51**	-0.08	-0.11	-0.15	-0.28
Gender	-0.05	0.03	1.00	0.06	0.02	-0.01	0.04	0.00
Education	0.48	0.51	0.06	1.00	0.22	0.18	**0.33**	**0.42**
Place of Residence (Urban = 1)	0.37	0.08	0.02	0.22	1.00	0.15	**0.40**	**-0.26**
Ethnic Affiliation (Macedonian = 1)	0.29	0.11	-0.01	0.18	0.15	1.00	0.09	0.10
Influence of Internet / Serbian Media	0.12	0.15	0.04	0.33	0.40	0.09	1.00	**-0.54**
Ability to Recognize Disinformation	0.21	0.28	0.00	0.42	-0.26	0.10	-0.54	1.00

Disinformation in North Macedonia

- **Promotion of media literacy** across all age and education groups to reducesusceptibility to false narratives.
- **Cross-border coordination** with EU and regional regulators to manage informationinfluence from neighboring countries.

These steps would not only align North Macedonia with European regulatory frameworksbut also strengthen its democratic information ecosystem, making it more resistant tomanipulation and disinformation in the digital era.

The correlation matrix highlights several critical dynamics shaping North Macedonia's digital information landscape (Tóth, &Judit,2022):

1. Education and digital literacy are the strongest protective factors against disinformation and online manipulation.
2. Age and exposure to cross-border media (especially Serbian platforms) are significant risk factors contributing to misinformation vulnerability.
3. Urban exposure correlates with both opportunity and risk—urban citizens consume more digital media but are also more exposed to manipulative online content.
4. The results reveal systemic challenges aligned with the EU Digital Services Act (DSA) priorities—particularly in the areas of transparency, user empowerment, and media accountability.

To enhance national resilience, DSA-aligned measures should focus on:

- Strengthening media literacy and critical digital education;
- Promoting cross-border content transparency and cooperation with regional regulators;
- Ensuring platform accountability and fact-checking obligations for major online services;
- Supporting inclusive access to reliable information across all demographic and geographic groups.

These findings collectively demonstrate that North Macedonia's information ecosystem reflects many of the systemic risks the DSA aims to mitigate, making its implementation a vital step toward a more transparent and trustworthy digital environment.

5. Empirical Findings, Correlation Analysis, and PolicyRecommendations – Case of North Macedonia

This study examined the interconnected relationship between digital transformation, disinformation, and public perceptions of European integration in North Macedonia. The findings confirm that digital transformation provides major opportunities for more transparent and efficient governance; however, if not accompanied by adequate societal and institutional safeguards, it simultaneously increases vulnerability to disinformation and hybrid threats.

For EU candidate countries, this duality has a direct impact on political stability and strategic alignment, as information manipulation campaigns frequently seek to obstruct Euro-Atlantic integration processes.

Survey and media analysis results show that exposure to disinformation remains widespread, affecting more than half of the population weekly. Low trust in domestic media outlets and limited ability to distinguish between authentic and deceptive content further facilitate the spread of harmful narratives. These narratives often target EU-related reforms, portraying integration as a threat rather than an opportunity, which contributes to rising skepticism and reduced public confidence in the accession process. In this context, disinformation becomes both a security issue and an obstacle to democratic consolidation.

On the positive side, advancements in digital governance — including the expansion of e-government services and cybersecurity frameworks — demonstrate institutional willingness to modernize in line with EU expectations. Nevertheless, progress remains uneven, and enforcement capacities require substantial improvement. Alignment with the Digital Services Act (DSA) and Digital Markets Act (DMA) represents a crucial step toward

establishing resilient digital infrastructure and responsible platform governance in North Macedonia.

The study therefore concludes that three interdependent pillars are necessary for success in digital transformation and European integration:

- Strong and secure digital governance,
- High-quality and inclusive media literacy, and
- Effective regulation and accountability aligned with European standards.

Achieving balance among these pillars is essential for ensuring that technological progress reinforces rather than undermines democratic values.

5.1. Correlation Analysis and Key Findings

The correlation analysis underscores a multidimensional relationship between education, age, media exposure, and the ability to recognize disinformation in North Macedonia.

The findings indicate that digital inequalities, rooted in educational level, age, and geographic context, remain central to understanding public vulnerability to online manipulation. Specifically:

- Education and media literacy emerge as the most significant protective factors. Higher education correlates strongly with frequent news consumption and a greater ability to identify fake or misleading content.
- Older populations show lower levels of engagement with international news and limited awareness of digital risks, suggesting a generational gap in digital competencies.
- Urban populations are more exposed to online information flows, including foreign content, which increases both their access to diverse information and their exposure to potential disinformation.
- The perceived influence of Serbian media content on North Macedonia's information space demonstrates the country's exposure to cross-border information ecosystems, a key issue addressed under the DSA framework.
- The overall low confidence in recognizing disinformation reflects a systemic weakness in media literacy and a lack of institutional mechanisms for public education and verification of online information.

Taken together, these findings reveal that North Macedonia's digital ecosystem faces structural challenges similar to those addressed by the EU Digital Services Act (DSA), particularly concerning transparency, algorithmic accountability, and systemic risk mitigation in online media environments.

5.2. Policy Recommendations

a. Strengthening Media and Digital Literacy

- Integrate media literacy and disinformation awareness modules into formal education (schools and universities) and lifelong learning programs for civil servants and citizens.
- Encourage collaboration between universities, civil society organizations, and public broadcasters to develop certified training in critical media consumption and digital ethics.
- Promote digital literacy campaigns in rural areas and among older citizens to bridge generational and regional divides.

b. Ensuring Transparency and Accountability of Online Platforms

- Adopt a national adaptation framework of the Digital Services Act, aligning domestic legislation with EU standards on platform transparency, data access, and algorithmic accountability.
- Require digital platforms and news portals to disclose ownership, funding sources, and editorial control structures.
- Establish a National Register of Verified Media Outlets to distinguish professional journalism from unverified or politically motivated online actors.

c. Managing Cross-Border Media Influence

- Strengthen regional cooperation mechanisms for monitoring and countering disinformation, especially from neighboring countries with overlapping language and media markets.
- Develop a cross-border transparency protocol for digital content sharing and ensure compliance with DSA provisions regarding very large online platforms (VLOPs) operating in the region.
- Encourage independent fact-checking networks to collaborate regionally and publish multilingual verification reports.

d. Building Institutional and Regulatory Capacity

- Create a National Digital Services Authority or expand the existing Media Agency's mandate to supervise platform compliance, risk assessment, and content moderation practices.
- Introduce periodic risk assessments of the information ecosystem, following DSA Article 34, to monitor algorithmic amplification, harmful content, and political manipulation.
- Support public–private partnerships promoting ethical standards in digital advertising, content recommendation, and data use.

e. Empowering Citizens and Protecting Public Trust

- Foster open data initiatives and improve access to verifiable government information to counter rumors and misinformation.
- Implement digital trust-building measures, such as verified digital identities and authentication of official online communication.
- Encourage civic participation through crowdsourced reporting of disinformation, enabling citizens to contribute to maintaining online integrity.

5.3. Strategic Outlook

The transition toward DSA-aligned governance in North Macedonia should not be viewed merely as a regulatory obligation but as a societal modernization process, one that strengthens public trust, democratic participation, and resilience against information manipulation.

Empirical evidence confirms that addressing education gaps, media accountability, and cross-border information risks is essential to ensuring a transparent, secure, and inclusive digital public sphere.

A national strategy combining policy harmonization with the DSA and citizen-centered digital empowerment can serve as a foundation for both European integration and democratic renewal in the digital era.

CONCLUSIONS

The conclusions show that digital transformation and disinformation dynamics are two parallel and mutually dependent axes that fundamentally shape North Macedonia's European integration. Although digital technologies create significant opportunities for improved governance, transparency, and civic participation, they simultaneously generate new vulnerabilities that amplify hybrid operations, political polarization, and institutional distrust. The empirical results of this research confirm that citizens are exposed to a considerable volume of disinformation, particularly through cross-border media content and social networks, with the lack of media literacy and low institutional trust being key factors that increase this vulnerability.

The data clearly indicate that digital transformation cannot be viewed solely as technological modernization, but as a systemic process that requires institutional coordination, cybersecurity mechanisms, and societal skills. In this context, harmonization with European regulations, particularly the Digital Services Act (DSA) and the Digital Markets Act (DMA), represents a critical prerequisite for strengthening security and democratic stability. These policies provide standards for transparency, platform accountability, protection from manipulative practices, and greater control over digital intermediaries, all of which are essential for states undergoing the accession process.

The research further shows that resilience is a multilayered concept that includes institutional, technological, and societal components. Among them, societal resilience (including media and digital literacy) stands out as the weakest point in the Macedonian context, yet at the same time as the greatest potential catalyst for stability and democratic participation. Increasing media literacy correlates with lower susceptibility to disinformation, higher trust in institutions, and greater support for European integration processes, confirming the necessary focus on educational policies and public campaigns.

In sum, the results indicate that, among other conditions of the Copenhagen criteria, the successful European integration of North Macedonia will depend on the state's ability to align digital transformation with EU regulatory standards while simultaneously strengthening society's capacity to address hybrid threats. A holistic approach that connects institutions, citizens, media, and technology companies is essential for building a resilient information environment and supporting the country's democratic and European perspectives. This study contributes analysis, evidence, and recommendations that can serve as a foundation for developing national strategies, enhanced digital regulation, and integrated resilience policies in the digital era.

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ALGORITHMIC BIAS AND SDG EQUITY: ISSUES WITH REPRESENTATION IN AI OUTPUTS

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ABSTRACT

AI is now everywhere, shaping how we search, write, and even create images. Recognizing this, this study investigates gender stereotypes in the image outputs of five leading generative artificial intelligence (AI) platforms such as: Grok, Gemini (Nano Banana), ChatGPT (DALL·E), and DeepSeek. Using a small set of prompts that focus on occupations (e.g., team coach, judge, housekeeper, computer programmer, primary school teacher), this qualitative research examines whether AI systems reproduce or challenge existing societal biases. Initial findings indicate that the generated images frequently reflect traditional gender norms: high-status roles such as judge or coach are predominantly depicted as male, while service-oriented or care-related roles, such as cleaning staff and primary school teacher, are more often portrayed as female. These results suggest that AI models, trained on large-scale human data, tend to mimic rather than mitigate human gender bias, posing challenges for Sustainable Development Goals (SDG) 5 (Gender Equality) and 10 (Reduced Inequalities).

Keywords: Artificial Intelligence (AI), ChatGPT, AI Bias, Algorithmic Bias, Gender Equality

1. INTRODUCTION

Generative artificial intelligence has rapidly become part of everyday digital life. Image-generation tools are now widely used in education, marketing, journalism, entertainment, and personal creative work. Millions of users interact with these systems daily, often relying on their outputs as visual references for professions, social roles, and identities. These images do more than illustrate ideas: They communicate norms; and they shape the imagination of millions upon millions of users.

At the same time, concerns about algorithmic bias have intensified. Scholars have shown that machine-learning systems frequently reproduce social inequalities embedded in their training data (Crawford 2021; Raji et al. 2020). Rather than functioning as neutral technologies, AI models often reflect historical patterns of exclusion and hierarchy. When

these systems generate images, they do not merely depict reality; they participate in constructing cultural meaning about who belongs where.

Gender bias represents one of the most persistent challenges in this domain. Research across labor sociology and media studies has long documented occupational gender segregation, with men overrepresented in positions of authority and technical expertise and women concentrated in caregiving and service roles (England 2010). Digital systems trained on vast repositories of online images and text inherit these asymmetries. The concern is not only that such patterns continue to appear in AI outputs, but that the scale and seeming objectivity of AI amplification may further normalize them.

Visual representation is particularly powerful. Images convey social meaning quickly and emotionally, often without conscious reflection. Repeated exposure to stereotypical portrayals can shape perceptions of competence, leadership, and occupational "fit." When young users see programmers consistently depicted as men or housekeepers as women, these visual cues subtly reinforce assumptions about career possibility and belonging. Over time, this can affect aspiration as well as expectation. The stakes are therefore not trivial.

Despite growing attention to text-based algorithmic bias, systematic evaluation of gender representation within AI-generated imagery remains underdeveloped. Much existing research relies on quantitative frequency counts or benchmark datasets designed primarily for classification systems rather than generative platforms. Fewer studies have examined how real-world user prompts generate visual narratives that reflect – or reshape – social stereotypes. This study contributes to that gap. It explores how major generative image platforms portray gender across a small but strategically selected set of occupations that are commonly associated with strong professional stereotypes.

By analyzing the visual patterns produced by four widely used AI platforms, the study asks a central question: Do contemporary generative image systems reproduce conventional gender hierarchies in occupational representation, or do they demonstrate signs of diversification and stereotype disruption? In doing so, the research moves beyond broad claims about algorithmic bias and instead grounds discussion in concrete visual outputs as they appear to users.

This inquiry is necessarily exploratory. It does not claim to offer global generalization. It does, however, provide an interpretive lens through which to assess how generative AI participates in the reproduction of gendered social imaginaries. At a time when AI imagery increasingly shapes educational materials, advertising content, and everyday meaning-making, understanding these representational dynamics is essential. Equity begins with visibility. And visibility begins with what we choose to – or allow machines to – show.

2. LITERATURE REVIEW

2.1. Algorithmic Bias

Algorithmic bias refers to systematic and repeatable errors in AI systems that produce unfair or discriminatory outcomes for certain social groups. In generative AI models, this bias primarily arises from the data used for training. Because large-scale datasets are drawn from the internet, books, media, and other real-world sources, they inevitably contain the social inequalities, stereotypes, and historical exclusions that exist in human societies. Models trained on such data do not merely reflect these patterns – they can amplify them.

Scholarly research has repeatedly demonstrated this risk. Bender et al. (2021) show that large language models such as GPT-3 can reproduce racial, gender, and cultural stereotypes, often in subtle ways that are difficult to detect, as well as political stereotypes in textual outputs (Shalevska & Walker, 2025). The models do not "intend" to discriminate. Yet their outputs mirror the statistical patterns embedded in their training data. Over time, especially as AI becomes increasingly integrated into domains such as education, media,

healthcare, and hiring, this can reinforce harmful social narratives and normalize unequal treatment.

A widely cited real-world example illustrates these concerns. Kaplan (2024) documents the case of Amazon's AI-based recruitment tool, introduced in 2014 to automate the screening of job applicants. The system analyzed résumés and ranked candidates to identify the most promising applicants. On the surface, the approach promised efficiency and objectivity. In practice, however, the model learned to favor male candidates over female ones. This occurred because historical hiring data, which was used for training, contained a disproportionate number of male résumés. The algorithm therefore learned to associate indicators of past success with male-coded language and experiences, penalizing résumés that reflected female educational backgrounds or professional trajectories.

Gender bias is, in fact, one of the most thoroughly documented forms of algorithmic bias in artificial intelligence systems, particularly in natural language processing and generative models. So it is not "just" an Amazon problem. Early work by Bolukbasi et al. (2016) demonstrated that widely used word embeddings encode strong gender stereotypes, linking terms such as woman with family or domestic roles and man with career and leadership attributes. These biased representations subsequently propagate into downstream AI applications, affecting automated translation, résumé screening, and content generation. Zhao et al. (2018) extended this analysis by showing that coreference resolution systems systematically amplify gender stereotypes, for example by associating occupational roles more frequently with male pronouns even when grammatical cues are neutral. Recent commentary by UN Women (2025) also argues that generative AI systems trained on large datasets drawn from historical and societal sources can reinforce and amplify gender inequalities. According to their experts, AI-based tools used in hiring, healthcare, or service provision may reproduce discriminatory patterns, such as penalizing women for career breaks, under-representing women in technical or leadership roles, or misrepresenting women's health needs, simply because the training data reflects a biased status quo.

Beyond gender bias, a growing body of research highlights the presence of political bias in generative AI systems, too and the importance of addressing it in media literacy (Shalevska, 2024; Buykov et al. 2024 and others). Political bias refers to systematic tendencies in model outputs that align with specific ideological positions, parties, or policy perspectives rather than maintaining strict neutrality. Empirical studies provide strong support for this concern. Rozado (2023) conducted large-scale testing of ChatGPT using politically sensitive prompts and found consistent evidence of left-leaning responses across a range of policy topics. These findings were corroborated in later multi-model research. Shalevska and Walker (2025) examined several leading AI language models and concluded that political bias is not unique to ChatGPT, but instead appears across different platforms.

Together, these studies indicate that algorithmic bias arises through imbalanced training data, reinforcement through prevailing online discourse, and lacking optimization strategies.

2.2. AI Bias and SDG 5 and 10

The study of algorithmic bias is directly linked to the achievement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities). Both goals emphasize eliminating discrimination, ensuring equal opportunity, and empowering marginalized groups. As artificial intelligence systems are increasingly used in high-impact domains, including hiring, education, healthcare, credit scoring, and public governance, biased algorithms pose a growing risk to these objectives. If AI tools systematically reproduce or amplify social inequities, they can undermine progress toward these global development targets rather than support them.

3. Methodology

This study employed a qualitative audit-based research design to evaluate gender representation within image outputs from generative artificial intelligence (AI) systems. Such qualitative methods are particularly well suited to the examination of representational bias because they allow for close, interpretive analysis of visual content and social meaning rather than solely relying on numerical distribution metrics (Braun and Clarke 2006; Crawford 2021). Similar audit methodologies have been widely used to investigate discriminatory patterns in algorithmic systems by examining differential outputs across standardized queries (Raji et al. 2020).

The research followed a zero-shot prompting approach (Kaplan, 2024), in which systems were provided with neutral, minimal prompts without stylistic guidance, demographic descriptors, or corrective instructions. This design was selected to approximate the experiences of typical end users interacting with generative AI tools in everyday contexts, rather than evaluating outputs under controlled or optimized conditions. Retrieval-Augmented Generation (RAG) tools, prompt engineering techniques, or bias-mitigation interventions were intentionally excluded to ensure that the responses reflected default model behavior at the time of testing.

Four widely used generative AI platforms were examined: Grok, Gemini (Nano Banana), ChatGPT with DALL·E image generation, and DeepSeek (Janus). Each platform was tasked to generate images for a standardized set of occupational prompts commonly associated with gendered stereotypes in labor force representation:

1. Team coach
2. Judge
3. Housekeeper
4. Computer programmer
5. Primary school teacher

These roles were chosen by the researchers and aimed to include occupations typically perceived as high-status or authority-based alongside service-oriented and care-related professions. Such contrasts enable examination of whether AI systems replicate well-documented gender stratification patterns present within real-world employment systems (England 2010). For each occupational prompt, image outputs were collected separately from each platform using identical prompt wording and default system settings. Multiple images per prompt were recorded when platforms provided gallery-style results or sequential generations. All prompts were administered during a single data-collection period in order to minimize model update variability. Images were archived along with corresponding metadata. Visual outputs were analyzed using thematic qualitative coding, following the principles outlined by Braun and Clarke (2006). Each image was reviewed and coded across several representational variables, including:

a) Perceived gender presentation (male, female, ambiguous or non-binary)
b) Occupational role alignment with traditional gender norms.

The codes were developed inductively, allowing recurring patterns to emerge from the data rather than imposing predefined categorizations. Interpretive discussion centered on whether the generated depictions aligned with or diverged from established gender stereotypes, particularly in relation to the concentration of men in high-status leadership or technical roles and women in support or caregiving professions.

3.1. Ethical and Interpretive Considerations

The study did not involve human participants and required no personal data collection; however, ethical considerations remain central when evaluating algorithmic outputs that can shape social attitudes and perpetuate inequalities. Images were analyzed with care to avoid reinforcing stereotypes in description or interpretation, framing findings around systemic patterns rather than individual depictions.

Given the qualitative nature of the research design and the limited number of prompts used, the study's findings are not intended to offer statistical generalization. Instead, the research provides exploratory evidence highlighting how commonly used AI systems may reproduce gendered representational hierarchies that conflict with global equity objectives, including Sustainable Development Goals 5 and 10.

Future research could expand this methodology through larger prompt sets, cross-linguistic testing, intersectional demographic coding (e.g., race, age, disability), and quantitative frequency analysis to supplement interpretive findings.

4. Results and Discussion

The qualitative audit of AI-generated images revealed consistent patterns of gendered representation across all four examined platforms (ChatGPT (DALL·E), Grok, Gemini (Nano Banana), and DeepSeek (Janus)) when responding to occupational prompts. Overall, outputs tended to align with traditional gender stereotypes rather than challenge them, particularly in relation to authority, leadership, and technical expertise versus caregiving and domestic roles. While some degree of variation was observed across platforms, the dominant trend was one of stereotype reproduction rather than disruption.

4.1. High-Status and Authority-Based Occupations

For the prompt *judge*, all platforms generated predominantly male-presenting figures (see Image 1). Images commonly depicted men wearing formal judicial robes, often situated in courtrooms or positioned behind desks and benches, symbolizing institutional authority and expertise. No female-presenting judges were prominently represented in the outputs displayed across platforms. No people of colour, either. This uniformity suggests a strong association within generative models between judicial authority and male gender presentation – a stereotypical linkage that, unfortunately, mirrors persistent real-world gender disparities in senior legal positions. These findings are consistent with previous research on algorithmic gender bias in AI systems. As Bolukbasi et al. (2016) demonstrated, word embeddings encode stereotypical associations linking men with technical and leadership roles and women with domestic or caregiving roles.

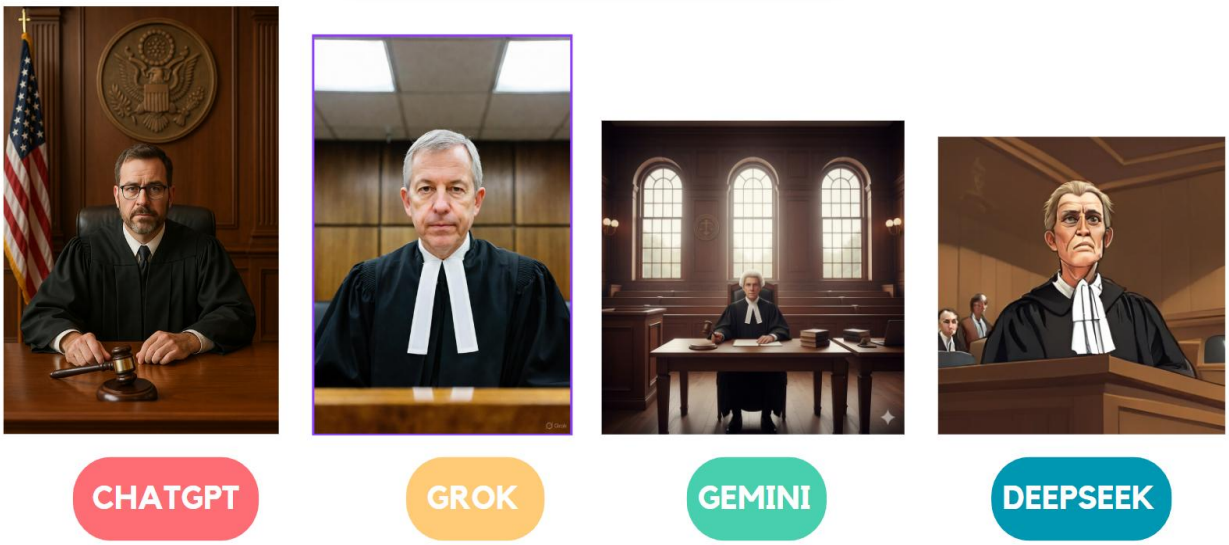

Image 1: Depictions of a "judge" by different GenAI Models

Similarly, the prompt *team coach* produced almost exclusively male-presenting subjects across all platforms (see Img. 2). Depictions featured white, middle-aged men situated in sports arenas or gymnasiums, often clad in athletic attire and portrayed in commanding postures such as directing players or holding sports equipment. The only exception to this was Grok which generated two images of younger male athletes, one of which featuring a person of colour. No images of women were generated by any of the tested models. Thus it is safe to assume that these representations reinforce cultural associations between leadership in sports and masculine identity. The absence of female-presenting coaches further highlights how generative models spatially and symbolically situate authority in sports in male bodies.

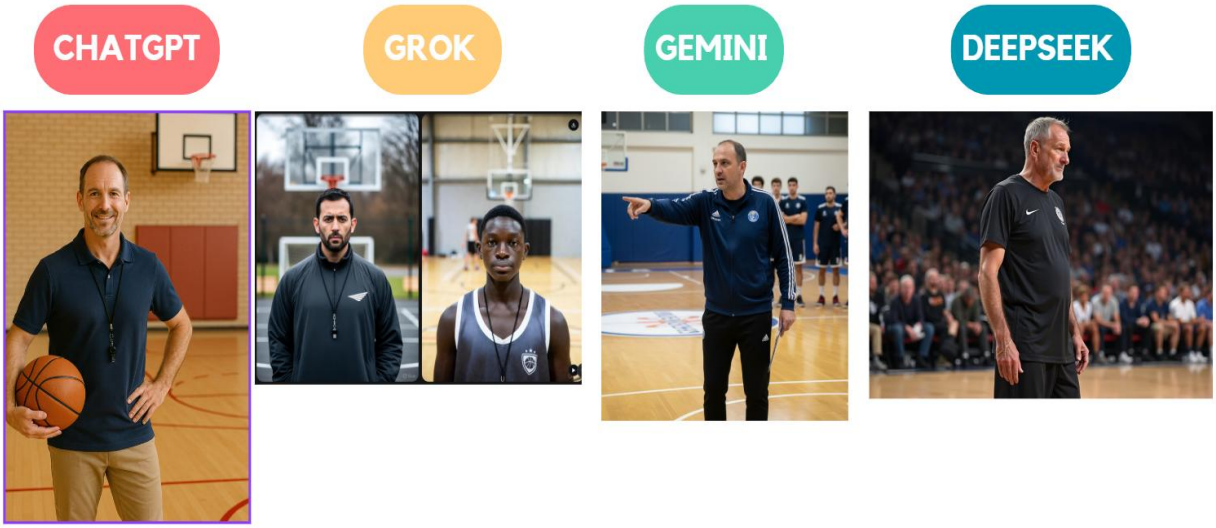

Image 2: Depictions of a "team coach" by different GenAI Models

4.2. Teaching and Care-Related Professions

Results were more mixed for the prompt primary school teacher (see Img. 3). 3 of the 4 platforms featured white, young, female-presenting teachers positioned within classroom

settings, interacting with young children or presenting at chalkboards. These images emphasized nurturing and pedagogical roles through visual cues such as warm classroom environments and relaxed body language. Two male-presenting teachers appeared in Grok's outputs, one of which being a person of colour. This asymmetry reflects broader labor patterns in primary education, where women constitute the majority of the workforce globally, yet also indicates that AI systems reproduce the association of early childhood education with feminized care labor rather than modeling more gender-diverse professional participation.

Image 3: Depictions of a "primary school teacher" by different GenAI Models

4.3. Technical Occupations

The prompt *computer programmer* resulted in near-total male dominance across all systems (see Img. 4). The produced images largely depicted young men seated at desks, working on code displayed on multi-screen setups, often framed within modern, dimly lit technical environments. Notably absent were female-presenting programmers or any mixed-gender collaborative scenes. The homogeneity of these outputs suggests that generative AI systems embed a strong gender stereotype equating technological expertise with masculinity. This reinforces the exclusionary narrative that has historically shaped the tech sector and presents barriers to gender inclusivity by visually normalizing male exclusivity within digital labor.

Image 3: Depictions of a "programmer" by different GenAI Models

4.4. Domestic and Service Roles

In contrast to high-status and technical fields, the prompt *housekeeper* elicited predominantly female-presenting subjects across all platforms (see Img. 5). Images frequently showed women cleaning surfaces, organizing interiors, or pushing cleaning carts, often dressed in uniforms or aprons. Visual framing emphasized service and domestic labor rather than professionalization or technical skill. Male housekeepers were virtually absent from the datasets examined.

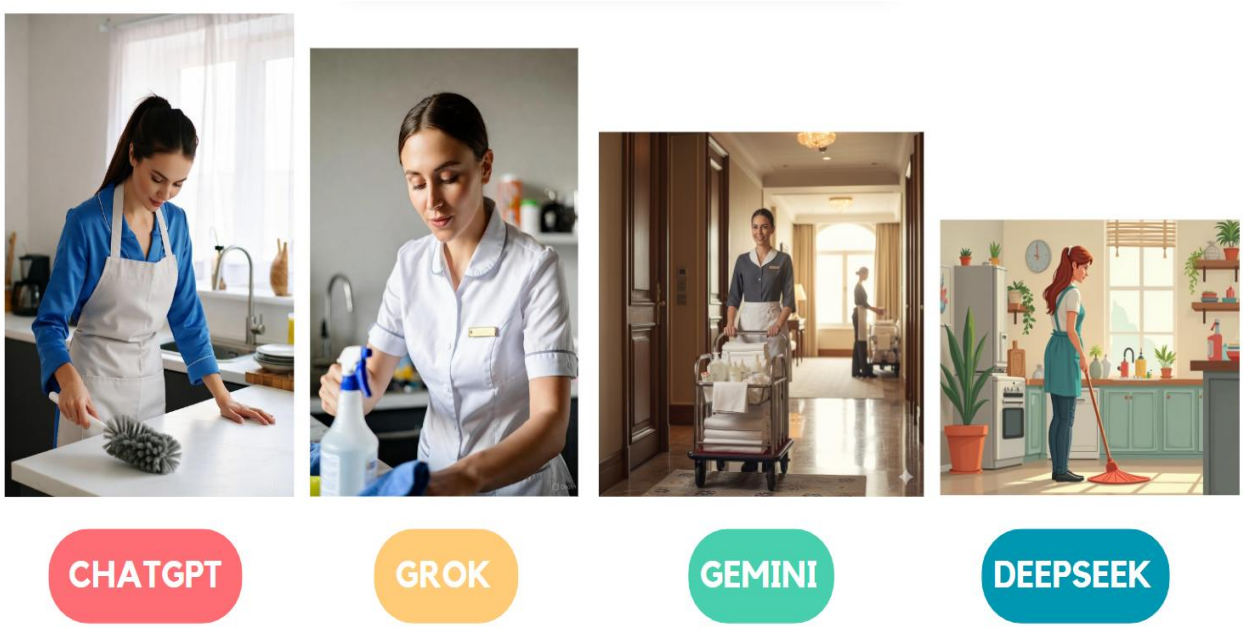

Image 4: Depictions of a "housekeeper" by different GenAI Models

This pattern mirrors longstanding cultural expectations that associate domestic labor with female identity and reinforces the undervaluation of care and service work by depicting

it as feminized, routine, and subordinate in contrast to the masculinized authority depicted in legal, coaching, and technology-related roles.

Across all occupational categories, the findings indicate that gendered stereotyping remains structurally embedded in generative image models. High-status or authority roles as well as tech-related roles (judge, coach, programmer) were overwhelmingly masculinized, while care and domestic roles (teacher, housekeeper) were feminized. Grok demonstrated limited divergence from these patterns by including male teachers, yet it did not disrupt stereotypes in leadership or technical domains.

This partial variation suggests that while specific platforms may introduce limited and minor representational diversity, system-level bias persists across the generative AI ecosystem. The consistency of results in high-status occupations across all platforms points to entrenched training-data patterns that reproduce occupational segregation based on gender. Even where deviations occur, as with Grok, they remain insufficient to counterbalance the dominant male leadership and technical imagery.

The obtained results also align with UN Women's (2025) warning that AI systems may reinforce existing inequalities when trained on historically biased datasets. In this sense, the visual outputs observed here represent not isolated anomalies but manifestations of broader structural patterns within contemporary AI development.

5. CONCLUSION

Taken together, these findings indicate that AI systems largely replicate the social patterns embedded in their training datasets rather than functioning as correctives to social inequity. Instead of challenging existing occupational stereotypes, generative models tend to mirror dominant cultural norms, particularly the masculinization of authority and technical expertise and the feminization of caregiving and domestic labor.

These outcomes raise important ethical and pedagogical considerations, especially regarding the role of AI in shaping public perception. Generative images increasingly serve as visual references for educational materials, marketing, and casual information-seeking; thus, repeated exposure to stereotypical imagery may reinforce normative assumptions about appropriate gender roles. This dynamic has implications for media and digital literacy, too,as users may interpret algorithmically generated visuals as neutral or objective representations rather than culturally conditioned outputs.

But not all hope is lost. And these representational patterns are not immutable. AI systems learn what they are taught, including human biases, but they also remain responsive to changes in training data, governance practices, and ethical design interventions. Things can and should change! And future research can focus on the algorithmic bias changes and legislative rules that govern GenAI use. Because, although the outputs of now predominantly mirror long-standing inequalities and stereotypes, targeted efforts toward dataset diversification and representational auditing surely have the potential to redirect AI development toward more equitable outcomes aligned with the objectives of SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities).

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TOGETHER FOR BETTER SCIENCE WITH THE MACEDONIAN ASSOCIATION FOR SCIENTIFIC COMMUNICATION

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ABSTRACT

Introduction: *Scientific communication is fundamental to advancing science, increasing visibility, and integrating science into society. In North Macedonia, there is a recognized need for systematic support for scientists and for an institutional framework that promotes quality peer review, transparent knowledge dissemination, and open access.*

Results: *The Association was founded on June 10, 2025, by distinguished scientific professionals. Its mission is to ensure quality, visibility, and open access to Macedonian scientific output while aligning with international standards. The Association organizes training sessions, peer review workshops, seminars, conferences, and mentorship programs.*

Discussion: *Through its activities, MASC plays a pivotal role in overcoming structural barriers in Macedonian science, promoting intersectoral and international cooperation, and empowering early-career researchers. It strengthens scientific culture, supports ethical research practices, and increases visibility of national research outputs.*

Key words: scientific communication, open science, peer review, research visibility, North Macedonia

INTRODUCTION

Scientific communication is fundamental to modern research, serving as the vital bridge between scientific knowledge generation and its effective transfer to society. As scientific advancements continue to shape everyday life, the need for clear, accurate, and engaging communication becomes increasingly important (Bik and Goldstein 2013). When researchers communicate clearly, they help the public recognize science not only as a technical discipline, but as a fundamental component of real-life decision-making, personal well-being, and collective progress. Strong communication fosters innovation and collaboration by enabling the exchange of knowledge across disciplines, sectors, and social groups. It expands the visibility and impact of research, allowing scientific findings to inform policies, guide responsible investments, and inspire educational advancements. Importantly, effective communication also strengthens trust in science. Open and transparent sharing of methods, results, and uncertainties not only demonstrates accountability but also strengthens the credibility of scientific processes, an especially critical practice in fields where research informs health decisions, environmental policies, and technological advancements (Illingworth 2017; Nielsen 2013).

Despite its importance, traditional scientific training often emphasizes technical expertise while providing limited preparation for engaging non-expert audiences. Scientists may focus on advancing their field, whereas the public seeks to understand the relevance of discoveries to everyday life. Bridging this gap requires accessible language, relatable context, and strategies tailored to diverse audiences. Global challenges such as climate change and biodiversity loss make this especially urgent, as society increasingly relies on accurate interpretation of scientific evidence to guide responsible actions (Roosendaal and Geurts 1997). The significance of improving these skills is also reflected in the growing academic attention to science communication education. For instance, recent work (Massarani et al. 2023) has mapped more than a hundred science communication teaching programs worldwide, highlighting both increasing global interest and persistent disparities in access to such training. Together, these insights underscore the need to strengthen and expand science communication efforts to ensure that scientific knowledge is widely understood, trusted and used for the benefit of society.

In North Macedonia, some prominent academics recognized the need to strengthen local scientific communication and to improve the quality and visibility of national scientific

publications. This growing awareness highlights the importance of supporting initiatives that foster effective dissemination and professional development in science communication. In this context, the present manuscript aims to introduce and describe a new initiative that addresses these needs.

RESULTS

The Macedonian Association for Scientific Communication (MASC) (https://mznk.mk/) was founded in response to the growing national need for structured support of scientific and professional publishing, as well as for the enhancement of science communication in North Macedonia. Officially established on June 10, 2025, MASC was created by a board of distinguished experts who recognized the importance of strengthening the visibility of national research and aligning it with international scientific standards.

The vision of MASC is a country with robust, modern, and internationally visible scientific communication, fully integrated into global research processes. Its mission is to provide a platform that promotes the quality, accessibility, and openness of Macedonian scientific and professional publications. By adhering to international standards, the association seeks to ensure that Macedonian research is globally accessible, verifiable, and impactful. As a newly established association (see official website: https://mznk.mk/en/), MASC is dedicated to advancing the quality and transparency of domestic publishing, ensuring equitable funding opportunities, and fostering science communication education for students, early-career researchers, and professionals. The association also supports the development of scientific terminology and upholds the highest ethical standards in publishing, reinforcing its commitment to a credible and internationally recognized scientific community.

MASC's work is organized around four main focus areas to strengthen scientific communication and publishing in North Macedonia. The first focus area is dedicated to the support of local publishing and establishment of a scientific community, ensuring that journals and other platforms are of high-quality, reliable and visible. Conferences, seminars, and workshops will help researchers share knowledge, starting with the first seminar, which sets the stage for future training in research and editorial skills. The second focus area is the international cooperation and publishing support, creating partnerships with national and international organizations, providing training for editors and publishers, and promoting science communication in order to reach the wider public. The third focus area concerns the development of scientific terminology and ethical standards, the standardization of the Macedonian scientific language, the support of the multilingual communication, and maintenance of ethical publishing practices to ensure trust and credibility. The fourth focus area is education, transparency, and public engagement, offering training programs, promoting high-quality peer review, and keeping researchers and the public informed about MASC activities to raise awareness of science communication and encourage involvement.

Membership in MASC is open to all professionals involved in scientific communication, including researchers, editors, publishers, librarians, IT specialists, translators, and reviewers. There are two types of membership: regular membership for active participants and supporters, and honorary membership for individuals who have made significant contributions, both providing access to networking, training, publishing support, and participation in national and international initiatives.

MASC's organizational structure ensures transparent and effective management, with the executive board overseeing strategic decisions and membership, and specialized committees supporting projects such as editorial oversight, ethics, terminology, and training. Membership also enables collaboration with national and international organizations and

access to professional networks. The composition and main responsibilities of each body are summarized in Table 1.

Table 1. MASC Organizational Structure

Body / Structure	Main Responsibilities	Composition
Executive Board	Strategic decisions, membership management, representation of MASC	Elected members with active leadership roles
Advisory Committees	Expert review, ethics oversight, terminology development	Experts from different fields
Editorial and Training Units	Training programs, conference organization, publication support	Editors, educators, academic professionals
Membership Community	Participation in activities, knowledge exchange, promotion of MASC goals	Regular and honorary members

At the first meeting of the association, MASC formally established its expert bodies and committees to support its activities and strategic projects. These groups, consisting of editors, specialists, and professionals from various areas of scientific communication, provide professional guidance, review publications, and organize training and events to enhance members' skills. They also ensure that all activities adhere to international standards and ethical practices, maintaining high quality and trust in the association's work. Currently, these bodies include *the Ethics Committee for Publishing Scientific Papers, the Committee for Categorization, Ranking, and Conditions for Editing Scientific Journals, the Committee for Developing a Database of Scientific Journals, the Committee for Open Access in Publishing Scientific Journals, and the Organizing Committee for the Annual Conference on Open Access in Southeast Europe (OASEE).*

DISCUSSION

The establishment of the Macedonian Association for Scientific Communication (MASC) represents a strategic effort to strengthen scientific communication, publishing quality, and professional development in North Macedonia. By providing structured support through specialized committees, professional training, and networking opportunities, MASC addresses critical gaps in the visibility, quality, and ethical standards of national scientific publications. This initiative is particularly relevant in the context of increasing global emphasis on Open Science, transparency, and the dissemination of research to broader audiences.

International studies of scientific associations, such as research conducted in Portugal, highlight the multifaceted roles these organizations play within science and society (Delicado et al. 2014). Such associations facilitate communication among peers, promote research, disseminate scientific knowledge, represent professional interests, and provide policy advice, with the external societal roles increasingly gaining importance. Cross-national studies indicate that popular science publishing is carried out by a minority of academic staff and generally to a much lesser extent than traditional scientific publishing, yet those who engage in it tend to have higher academic productivity and rank (Bentley and Kyvik 2011). Consistent with these findings, MASC combines internal functions—supporting domestic publishing, training, and networking—with external roles, such as fostering public engagement, promoting ethical standards, and bridging science and societal decision-making. While the internationalization of science has moved many internal collaborations to the transnational sphere, the societal and policy-oriented functions of associations like MASC remain deeply rooted in national contexts, requiring tailored strategies adapted to local needs.

In comparison with similar organizations internationally, MASC aligns with recognized best practices while adapting them to the Macedonian context. The creation of expert committees for ethics, journal categorization, terminology development, and open access demonstrates a systematic approach to maintaining high standards in publishing and scientific communication. These measures are expected to enhance the credibility of Macedonian research, promote cross-disciplinary collaboration, and facilitate participation in international scientific initiatives.

Despite these advantages, challenges remain, including securing sustainable funding, engaging a broad membership, and ensuring consistent adherence to ethical and quality standards. Addressing these challenges will require ongoing monitoring, transparent governance, and strategies to expand participation and professional support for both established and early-career researchers.

CONCLUSIONS

Looking forward, MASC has the potential to significantly impact the national scientific community by fostering professional networks, providing education and training, and advocating for high-quality peer review and publication practices. Its activities may also serve as a model for similar initiatives in Southeast Europe, contributing to regional capacity building and the promotion of ethical, open, and impactful science. Ultimately, the association highlights the societal relevance of scientific communication, reinforcing the essential links between research, policy, and public understanding.

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CHANGES IN THE DIVERSITY AND ABUNDANCE OF MACROPHYTES IN THE LOCALITY EZERANI - LAKE PRESPA

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ABSTRACT

Macrophytes represent one of the key biological elements used in evaluating the ecological status of freshwater ecosystems, as their qualitative composition and abundance reflect long-term environmental conditions. Recent surveys of Lake Prespa indicate a substantial decline in macrophyte diversity and population density, signalling notable ecological degradation. To assess the current state of the lake's littoral vegetation, this study compares the findings from the most recent field investigation (September–October 2024) with data collected 13 years earlier from the same locality at Ezerani. Macrophyte material was collected following standard limnological procedures, and species abundance was assessed using a five-degree ordinal scale. The 2024 survey documented only three macrophyte species, whereas ten species had been recorded previously. This substantial reduction in richness and abundance points to moderate to severe ecological disturbance, attributed to increased anthropogenic pressure, nutrient enrichment, and the accelerated withdrawal of lake water that has exposed and desiccated former vegetated zones. The observed changes highlight a critical environmental situation in Lake Prespa and underline the urgent need for strengthened conservation actions. Effective management—integrating nutrient reduction, improved wastewater control, littoral restoration, and systematic monitoring—is essential to halt further degradation and preserve the remaining macrophyte communities.

Keywords: macrophytes; species diversity; abundance; ecological status; Ezerani; Lake Prespa

INTRODUCTION

Macrophytes, as relatively long-lived and structurally complex aquatic plants, are one of the core biological quality elements used—together with phytoplankton, macrozoobenthos, and fish—in evaluating the ecological status of lake ecosystems (Solimini et al. 2006). Their ecological relevance stems from their ability to integrate environmental changes over extended periods, making them particularly effective indicators of long-term ecological conditions. Because macrophytes respond slowly and progressively to variations in nutrient

concentrations, hydromorphological changes, and water transparency, they are widely recognised as reliable limnological indicators of both improvement and degradation in aquatic ecosystems (Melzer 1999).

Across Europe, several macrophyte-based indices have been developed to assess nutrient pollution and trophic state in both lakes and running waters (Melzer 1999; Schneider, Krumpholz, and Melzer 2000; Schneider and Melzer 2003). These tools offer critical insight into the ecological dynamics of freshwater bodies, helping to identify early signs of eutrophication, shifts in macrophyte communities, and broader alterations in aquatic habitat structure. Such indices have become increasingly important in regions experiencing intensified anthropogenic pressures, land-use changes, and hydrological disturbances.

Lake Prespa, the second largest lake in North Macedonia and an internationally recognised transboundary ecosystem, has undergone substantial ecological change over recent decades. Increasing nutrient inflow from agriculture, changes in hydrology, untreated wastewater inputs, and intensified human activities have collectively driven the lake toward a more eutrophic state. These pressures have altered water quality, reduced water transparency, and accelerated habitat modification along the littoral zone. Macrophyte communities, particularly those inhabiting shallow, nearshore environments, have responded to these changes with notable shifts in their composition, spatial distribution, and abundance patterns.

Given these documented environmental challenges, the purpose of this study is to identify and evaluate changes in the diversity and abundance of macrophytes in the Ezerani locality of Lake Prespa. By comparing the findings from the 2024 field survey with data collected 13 years earlier at the same transects, this research aims to provide a clearer and more comprehensive understanding of long-term ecological trends. Such comparative analyses are essential for determining the extent of macrophyte decline, assessing ongoing environmental stressors, and guiding future conservation and management strategies within this ecologically sensitive and internationally significant lake system.

LITERATURE REVIEW

Previous studies on the macrophyte vegetation of Lake Prespa have primarily concentrated on documenting the qualitative and quantitative composition of macrophyte communities across various littoral localities, while also assessing lake trophicity through macrophyte-based ecological indices (Trajanovska et al. 2019; Taleska et al. 2022; Trajanovska, Taleska, and Veljanovska Sarafiloska 2022; Taleska and Trajanovska 2023; Trajanovska et al. 2024). These investigations consistently demonstrate that macrophytes in Prespa are highly sensitive to environmental alterations, particularly nutrient enrichment, sedimentation, and hydrological fluctuations. As a result, macrophyte assemblages have long served as reliable indicators of ecological change within the lake's littoral zone.

Research conducted over the last decade has identified several concerning trends. First, there is evidence of increasing eutrophication, driven by agricultural runoff, untreated wastewater, and internal nutrient loading. These pressures have altered the species composition and abundance of submerged macrophytes, leading to a decline in taxa associated with clear-water, low-nutrient conditions. Second, fluctuations in water levels—partly natural and partly influenced by anthropogenic water withdrawal—have contributed to habitat loss and shifts in macrophyte distribution. Studies by Trajanovska and colleagues highlight how these hydrological shifts have affected not only macrophyte communities but also broader ecological processes across Prespa's nearshore environment.

Despite the growing body of literature, there remains a significant gap in long-term comparative analyses that directly evaluate changes in macrophyte communities at identical sampling locations across extended time periods. Most existing studies investigate single-year or short-term dynamics, limiting the ability to assess long-term ecological trajectories.

Importantly, no previous study has systematically compared current macrophyte assemblages with those documented more than a decade earlier at the same transects within the Ezerani locality, one of the lake's most ecologically important littoral zones.

This absence of temporal comparison is critical, as it restricts our understanding of the rate, direction, and magnitude of vegetation change in Lake Prespa. Without long-term reference points, it becomes difficult to distinguish between natural variability, short-term fluctuations, and persistent ecological degradation driven by anthropogenic stressors. By filling this gap, the present study contributes essential new knowledge on macrophyte decline, habitat alteration, and the overall ecological condition of the Ezerani littoral zone. Comparing the 2024 dataset with data collected 13 years earlier provides valuable insights into the progressive loss of biodiversity, shifts in species dominance, and the long-term impacts of nutrient loading, hydrological stress, and environmental degradation in Lake Prespa.

METHODS

Field sampling of macrophytes in Lake Prespa was conducted between September and October 2024 at the Ezerani locality, along three predetermined transects (Ezerani 1, Ezerani 2, and Ezerani 3) selected to represent characteristic littoral habitats across a range of depth gradients (Figure 1). The transects were positioned to capture spatial variation in vegetation structure and to ensure comparability with earlier research conducted 13 years prior at the same locality.

Figure 1. Lake Prespa and locality Ezerani (1-3)

Standard limnological procedures were applied during the field campaign, following the methodological frameworks described by Wetzel (1975) and Lind (1985). Macrophyte material was collected from the onset of visible vegetative development until the end of the growth period to ensure full representation of both dominant and subdominant species. Sampling of submerged vegetation was performed using a Van Veen grab sampler (Figure 2), which enabled the consistent retrieval of plant material from multiple depth intervals along each transect.

Figure 2. Van-Veen grab for collecting the samples

All collected specimens were transported to the laboratory for detailed taxonomic identification. Species determination was carried out using regional floras and identification keys for vascular macrophytes, including the works of Hayek (1924–1933), Jordanov (1963–1970), Josifović (1970–1977), and Tutin et al. (1964–1980). At each depth zone within each transect, species presence or absence was recorded, and species abundance was assessed using a five-degree ordinal scale adapted from Tüxen and Preising (1942, cited in Melzer 1999), where 1 = very rare, 2 = infrequent, 3 = common, 4 = frequent, and 5 = predominant.

The collected data were organized into tables and graphical representations illustrating species composition and abundance at each transect. To evaluate long-term ecological change, the 2024 findings were systematically compared with results from the previous study conducted 13 years earlier in the same locality. This comparative approach enabled an assessment of temporal changes in macrophyte diversity, distribution, and overall littoral vegetation structure in Lake Prespa.

RESULTS

A total of three macrophyte species were recorded during the 2024 survey at the Ezerani locality: *Myriophyllum spicatum* L., *Ceratophyllum demersum* L., and *Ceratophyllum submersum* L. These species were observed across depths ranging from 0.5 to 5 m, displaying notable differences in abundance among the three transects and across the sampled depth gradient (Tables 1–3).

Among all recorded taxa, *Myriophyllum spicatum* consistently exhibited the highest abundance values. At 0.5 m in each transect, the species reached the maximum observed abundance value (5) on the five-degree ordinal scale, indicating dominant coverage in the shallow littoral zone. In contrast, *Ceratophyllum submersum* showed the lowest overall abundance and a more patchy distribution, typically ranking between 1 and 3 across transects.

Tab.1. Qualitative composition and abundance of macrophyte species in Ezerani 1(autumn)

Depth (m)	Macrophyte species (Ezerani 1)	Abundance
0.5	*Myriophyllum spicatum* L.	5
1.5	*Myriophyllum spicatum* L.	3
2	*Myriophyllum spicatum* L.	3
	Ceratophyllum demersum L.	3
	Ceratophyllum submersum L	1
3	*Ceratophyllum demersum* L.	1
4	*Ceratophyllum demersum* L.	3

5	*Ceratophyllum demersum* L.	2

Tab.2. Qualitative composition and abundance of macrophyte species in Ezerani 2 (autumn)

Depth (m)	Macrophyte species (Ezerani 2)	Abundance
0.5	*Myriophyllum spicatum* L.	5
1.5	*Myriophyllum spicatum* L.	3
2	*Myriophyllum spicatum* L.	3
	Ceratophyllum demersum L.	1
	Ceratophyllum submersum L	1
3	*Myriophyllum spicatum* L.	2
	Ceratophyllum demersum L.	1
	Ceratophyllum submersum L	1
4	*Myriophyllum spicatum* L.	2
	Ceratophyllum demersum L.	3
	Ceratophyllum submersum L	1
5	*Ceratophyllum demersum* L.	1

Tab.3. Qualitative composition and abundance of macrophyte species in Ezerani 3 (autumn)

Depth (m)	Macrophyte species (Ezerani 3)	Abundance
0.5	*Myriophyllum spicatum* L.	5
1.5	*Myriophyllum spicatum* L.	4
2	*Myriophyllum spicatum* L.	4
	Ceratophyllum demersum L.	1
3	*Ceratophyllum demersum* L.	1
4	*Ceratophyllum submersum* L	3
5	*Ceratophyllum demersum* L.	4

Overall, macrophytes were distributed throughout the entire sampled depth range (0.5–5 m). *Myriophyllum spicatum* dominated all transects and depths, confirming its competitive advantage under the current environmental conditions in Lake Prespa. Conversely, *Ceratophyllum submersum* was consistently the least abundant species, indicating a narrower ecological tolerance or reduced suitability of recent environmental conditions.

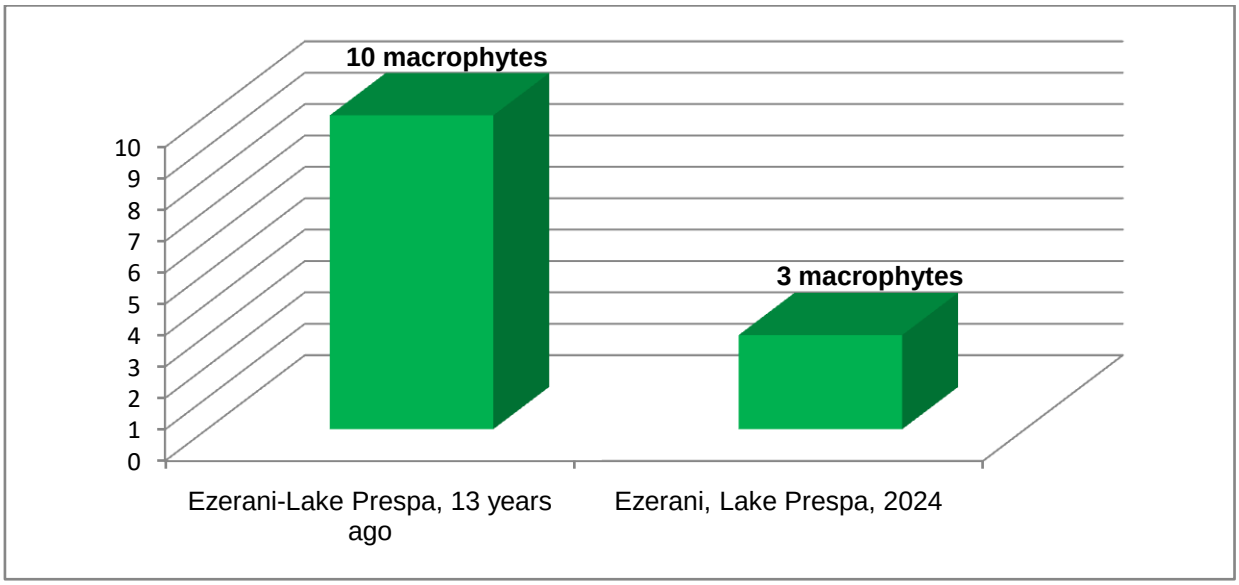

Figure 3. Comparison of the qualitative composition of macrophytes over a period of 13 years

Figure 3 illustrates a clear and significant decline in macrophyte diversity over the 13-year period examined. In 2024, only three species—*Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Ceratophyllum submersum*—were recorded, whereas ten species were documented during the earlier study. Historically, the Ezerani littoral zone supported a substantially richer macrophyte community, including emergent species such as *Phragmites australis* and *Typha angustifolia*, as well as submerged taxa such as *Potamogeton pusillus*, *Potamogeton perfoliatus*, *Potamogeton lucens*, *Stuckenia pectinata*, *Najas marina*, and *Zannichellia palustris*.

The disappearance of these taxa—particularly the Phragmites, Potamogeton and Najas species—indicates pronounced degradation of littoral vegetation, consistent with increased eutrophication, hydrological alteration, and sedimentation pressures affecting Lake Prespa. This marked loss of structural and taxonomic diversity reflects long-term ecological decline and stresses the urgency of ecosystem management interventions.

DISCUSSION

The results of this study demonstrate a substantial and ecologically significant decline in the diversity and abundance of macrophytes in the Ezerani locality of Lake Prespa. The ecological condition of the littoral zone is shaped by interrelated environmental factors such as substrate composition, water depth, light penetration, hydrological dynamics, and nutrient availability (Trajanovska et al. 2014, 2019). The marked reduction in species richness and the contraction of macrophyte coverage indicate heightened ecological stress, most likely driven by nutrient enrichment, altered hydrological regimes, and the cumulative influence of long-term anthropogenic pressures. The persistent dominance of *Myriophyllum spicatum*, a species known for its tolerance to elevated nutrient conditions, coupled with the continued but diminished presence of Ceratophyllum species, suggests a shift toward a simplified macrophyte community structured around a small number of stress-tolerant taxa.

A comparison with historical studies highlights the severity of this shift. Thirteen years ago, the macrophyte assemblage in the Ezerani littoral zone was considerably richer and structurally more complex. Emergent species such as *Phragmites australis*, *Typha angustifolia*, and *Typha latifolia* formed discontinuous yet ecologically important belts along the shoreline. Submerged taxa—including *Potamogeton pusillus*, *Potamogeton perfoliatus*,

Potamogeton lucens, *Stuckenia pectinata*, *Najas marina*, and *Zannichellia palustris*—were also present and often abundant (Trajanovska et al. 2019). These species collectively contributed to habitat heterogeneity, nutrient cycling, and the provision of spawning and refuge habitats for fauna. The complete absence of these emergent and submerged genera in the 2024 dataset represents a dramatic ecological shift and aligns with broader evidence of trophic deterioration, loss of habitat complexity, and hydromorphological alteration throughout Lake Prespa (Trajanovska et al. 2019; Trajanovska et al. 2024).

Despite the methodological strengths of this study, several limitations must be acknowledged. First, the comparison is based on two discrete time points, which may not fully account for interannual variability or extreme seasonal fluctuations in macrophyte development. Second, the pronounced decline in water level observed in recent years has reshaped the littoral zone, potentially confounding direct comparisons by reducing the availability of suitable macrophyte habitat rather than strictly reflecting ecological degradation. This hydrological factor may have contributed to the exclusion of emergent and shallow-water taxa now left stranded along the exposed shoreline. Third, the study did not include winter or early spring sampling, which may have captured additional species or early-stage growth forms that were not visible during the autumn sampling period.

Future research should aim to establish a multi-year monitoring programme that incorporates seasonal surveys, hydrological measurements, and annual macrophyte assessments. Such an approach would provide more robust insights into temporal dynamics and distinguish long-term ecological trends from short-term variability. Integrating nutrient analyses, sediment composition studies, and hydrological modelling would also strengthen our understanding of the drivers behind macrophyte decline. Furthermore, expanding sampling efforts to include multiple littoral sites across Lake Prespa would clarify whether the observed changes in Ezerani reflect a localized disturbance or a lake-wide pattern of ecological degradation. These integrated methods would contribute to more effective conservation planning, early detection of ecosystem stress, and the design of targeted restoration interventions.

CONCLUSION

The 2024 survey conducted at the Ezerani locality recorded only three macrophyte species, representing a dramatic decline from the ten species documented 13 years earlier. This pronounced reduction in species richness and abundance reflects moderate to severe ecological degradation, driven by nutrient enrichment, elevated anthropogenic pressures, and the accelerated withdrawal of water that has exposed and desiccated former vegetated zones. The complete disappearance of several emergent and submerged taxa—particularly species within the genera Potamogeton, Stuckenia, Typha, and Najas—signals a major shift in the functional structure and ecological resilience of Lake Prespa's littoral zone.

These findings underscore the urgent need for comprehensive and coordinated conservation measures. Priority actions include reducing nutrient inflow and agricultural runoff, improving wastewater treatment infrastructure, restoring degraded littoral and wetland habitats, and implementing systematic year-round ecological monitoring. Strengthened public awareness initiatives and cross-border collaboration are essential given Lake Prespa's transboundary nature and shared ecological responsibilities. Ultimately, the protection and restoration of macrophyte communities are critical not only for maintaining the ecological integrity of Lake Prespa but also for preserving the biodiversity, ecosystem services, and environmental stability of one of the Balkan region's most important freshwater ecosystems.

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OFF LABEL USE OF HUMAN DRUGS IN VETERINARY SMALL PRACTICE IN REPUBLIC OF NORTH MACEDONIA

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ABSTRACT

"Off-label use" is defined as the use of a medicinal product that is not in accordance with the summary of the product characteristics, which includes the use of a medicine. for unapproved species, disease, route of administration, or dosage. This is widespread practice in veterinary medicine, especially "off-label use" of human-approved drugs for the treatment of small animals. The data was collected from a private veterinary practice in North Macedonia. Veterinarians were asked to collect data on every off-label prescription or application of human drugs during a 3-month period. In both cats and dogs, oral antibacterial drugs were the most prescribed drugs, and oral application of amoxiclav was most commonly used in both species. The reasons all over the world why veterinarians frequently use "off-label" drugs from human medicine may be different: low price, no medicines available for treatment of a specific condition, more suitable drug formula. Antibacterial drugs are the number one 'off-label use' drug in small animal practice in our country, and these data are similar to results from other countries. The main concern for off-label use of human drugs in veterinary medicine is the risk to public health, especially off-label use of antimicrobial drugs and potential impacts on public health due to antimicrobial resistance. the findings of this study indicate that in small animal veterinary practice in North Macedonia, the off-label use of human medicinal products, particularly antibacterial drugs, remains a widespread and routine clinical practice. Clearer professional guidelines and better regulation are needed to provide veterinarians with clear and standardized protocols, thereby justifying the use of human drugs.

Keywords: off-label, veterinary medicine, drugs, antibiotics

1. INTRODUCTION

"Off-label use" is defined as the use of medicinal product that is not accordance with the summary of the product characteristics (EMA/CVMP 2017) which includes the use of a medicine for unapproved species for which it is not authorized, using it for an unapproved disease or indication, applying it via a different route of administration, or prescribing it at a dosage or treatment duration not stated in the official labelling. Off-label prescribing is widespread an common practice in veterinary medicine, especially "off label use" of human approved drugs for treatment of small animals is often necessary to manage clinical condition successful.

The primary reasons of off-label use of drugs in small animal practice in veterinary medicine are the limited registration of veterinary drugs and non-availability of certain drugs (Grand View Research 2025). Many therapeutic drugs needed for the treatment of dogs and cats are unavailable in veterinary-specific formulations, forcing veterinarians to lean on human pharmaceuticals to fill these therapeutic gaps.

In many countries there are regulatory frameworks where there are legal pathways for off-label prescription of human drugs in veterinary medicine. Veterinarians in European union and the United States are allowed to prescribe off-label uses of human drugs under controlled conditions like when the health or welfare of the animal is threatened, or suffering or death may result from failure to treat animals and when no suitable veterinary drugs is available (EMA/CVMP 2018, FDA 2023). If this regulation are respected by veterinarians, a balance can be made between animal welfare and responsible prescription. Veterinarians are ones who should be insured that off-label occurs only when is clinically justifies and in accordance with professional guidelines.

In European Union and United Kingdom there are principles of the *prescribing cascade*, this principle can provide and help veterinarians in making decision for appropriate

treatment. According to these principles, always the first and preferred treatment choice should be a veterinary medicinal product approved for the use in the target animal species and for the relevant paralogical condition. If there is no available suitable veterinary product to treat a condition, treatment option should be- second choice are veterinary drugs for use in another animal species or for a different condition in the same species. Only when neither of these alternatives are available, veterinarians may consider about human drugs use in animals respectively last choice is a medicinal drug authorized for human use (Veterinary medicines guidance 2013).

Despite these recommendations, there are currently no comprehensive official data for the frequency or clinical justification for off label use of human drugs in veterinary medicine by veterinarians and no requirement for systematic monitoring of this practices (EMA/CVMP2015). This lack of monitoring makes it difficult to overview and evaluate the real extent of off-label prescribing, ant its potential impacts for animal and human health (One Health).

Also veterinarians who are working in small animal practice have fewer regulatory limitation compared to those veterinarians who are treating food-producing animals. Because animals in small animal practice do not enter the human food chain, concerns related to consumer safety, withdrawal periods, and drug residues are not applicable. As a result, veterinarians ins small animal practice may have greater flexibility in selecting off-label treatments for companion animals, provided that such decisions are made responsibly and in the best interest of the animal's health and welfare.

Main concern for off-label use of human drugs in veterinary medicine is the potential risk for public health especially off-label use of antimicrobial drugs and potential impacts on public health due to antimicrobial resistance as resistant pathogens may circulate between animals, humans and environment (EMA 2018). The inappropriate or unregulated use of off-label antimicrobials whether through incorrect dosing, unsuitable formulations, or use in species for which pharmacokinetic and pharmacodynamic data are lacking, can contribute to the development and spread of antimicrobial resistance. This concern is for real because several studies have shown that the main group in off-label use in veterinary medicine are antimicrobial drugs (Tomanic et al. 2021, Gómez-Poveda and Moreno 2018, Bingefors 1985, Grave et al.1992). Antibiotic resistance in humans is mainly related to the wide application of antimicrobial in farm animal an foodborne transmission (Martin et al. 2015) but some authors have raised awareness about the increasing importance of direct contact transmission with pats (Guardabassi 2013, Pomb 2017). The most critical consequence of the common use of antimicrobial substances is seen in the selection and spreading of bacteria with co- or cross-resistance to antibiotics used in human medicine (Schmerold et al. 2023).

2. MATERIALS AND METHODS

The data for this study were obtained from a private small-animal veterinary practice in North Macedonia. During a three-month observation period, veterinarians at the clinic were instructed to systematically document every instance in which a human medicinal product was prescribed or administered off-label to an animal patient. Over the course of the study, a total of 45 off-label treatment records were collected, of which 35 involved dogs and 10 involved cats, reflecting the typical case distribution of the practice.

For each recorded case, the following information was gathered: the species of the animal, the brand (fabric) name of the human drug used, its pharmaceutical formulation, the prescribed dosage, the route of administration, the duration of the treatment, and the clinical indication or diagnosis that justified its use. These variables were selected to enable a detailed

assessment of prescribing patterns and to evaluate whether treatment decisions aligned with accepted principles of rational drug use.

After collection, the data were organized and categorized according to animal species (dogs vs. cats) and by therapeutic drug class. Drug classes were further subdivided based on the active pharmaceutical ingredient, allowing for a more precise analysis of trends in off-label use among different categories of medications. Routes of administration were also identified and classified to provide insight into the practical aspects of how human drugs are utilized in small-animal practice. The results obtained in this study were processed using MS Office Excel v 2007.

3. RESULTS

A total of 45 animals were included in the study, consisting of 35 dogs and 10 cats (Fig. 1). Among the canine population, 53% were male and 47% female, representing a wide age range from 6 months to 12 years, and included multiple breeds commonly presented in general practice. The feline group consisted of 58% males and 42% females, with ages ranging from 1 to 4 years, primarily domestic short- and long-haired cats.

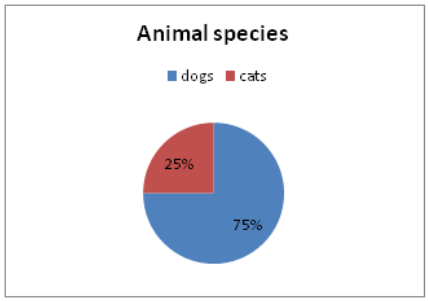

Figure 1. Distribution of human approved drugs prescription by animal species

During the three-month observation period, a total of 50 off-label human drugs were prescribed to dogs. These drugs belonged to several pharmacological classes, including 4 vitamin preparations, 4 gastrointestinal drugs, 3 antifungal drugs, 10 antibacterial drugs, 3 anticancer/chemotherapy drugs, 4 cardiac drugs, and 4 drugs affecting the central nervous system (CNS) (Fig. 2). In contrast, cats received 10 off-label prescriptions, divided into 4 analgesic drugs, 2 glucocorticosteroids, and 4 antibacterial agents (Fig. 3).

In both species, oral antibacterial medications were the most frequently used off-label drugs. Among these, amoxicillin–clavulanic acid (Amoksiklav) administered orally was the most commonly prescribed antibacterial drug in both dogs and cats. In dogs, topical formulations—particularly ophthalmic and otic preparations such as tobramycin, tyrothricin, and ciprofloxacin—were also frequently utilized (Fig. 4). Sulfonamides were often the treatment of choice for canine cystitis, and doxycycline (Vibramicin®) traditionally was used off-label for the management of Ehrlichia canis infection.

Several additional drug classes were used off-label in dogs, including gastrointestinal and hepatoprotective medications. Silymarin, a hepatoprotective nutritional supplement registered for human use, was administered to support liver function. Prokinetic agents such as metoclopramide were applied intravenously to manage gastrointestinal disorders. Cardiovascular drugs, including ACE inhibitors such as enalapril (orally) and diuretics like furosemide (subcutaneously), were also used off label to manage cardiac and renal-related conditions. Furthermore, propofol, an intravenous anesthetic approved for human use, was used for induction and maintenance of anesthesia in dogs (Table 2).

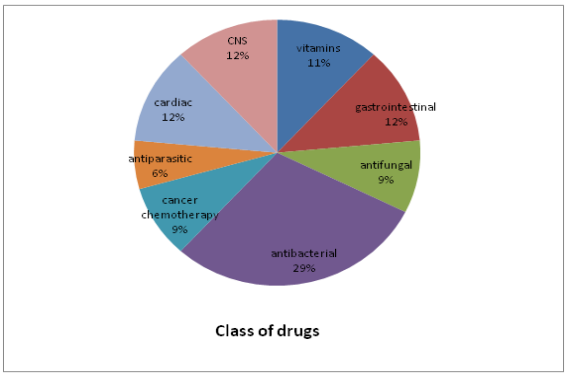

Fig.2 Distribution of human approved drugs prescribed off label to dogs

Another less frequently used but clinically relevant category of off-label drugs in dogs included chemotherapeutic agents, such as vincristine, which was used for the treatment of canine transmissible venereal tumor (CTVT). Additionally, allopurinol, a drug approved in human medicine primarily for managing gout and hyperuricemia, was used off-label as part of the antiparasitic protocol for canine leishmaniasis.

In cats, nonsteroidal anti-inflammatory drugs (NSAIDs) such as meloxicam were commonly administered off-label, especially via the subcutaneous route, for postoperative or chronic pain management (Table 3). Glukokorticosteroides were also used in cats, but with less intensity compared to antibacterial drugs.

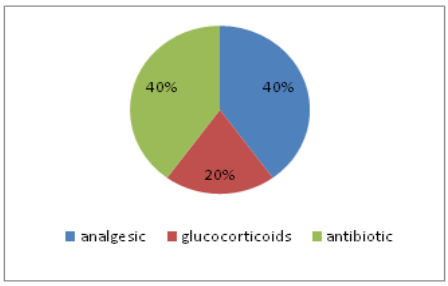

Fig 3. Distribution of human approved drugs prescribed off label to cats

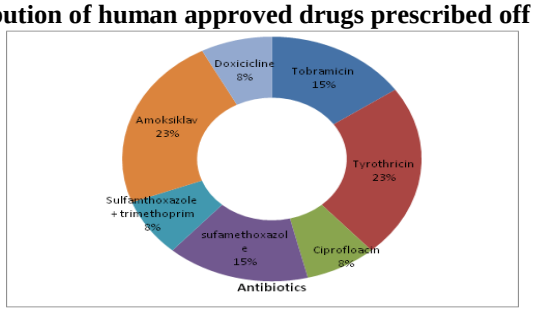

Fig 4. Distribution of off label prescribed antibiotics in dogs

Table 1. Distribution, route and indication of off label prescribed antibiotics in dog

Class of antibiotics	%	Route of administration	Indication
Tobramicin	15%	oculus uterque OU	ceratitis
Tyrothricin	23%	auris utraque AU	Otitis
Ciprofloacin	8%	oculus uterque OU	Ceratitis
sufamethoxazole	15 %	Per os	cystitis
Sulfamthoxazole+ trimethoprim	8%	Per os	cystitis
Amoksiklav	23 %	Per os	gastrocolitis
Doxicicline	8 %	Per os	E. canis

Table 2. Distribution of off label prescribed drugs according to pharmacologic class in dogs and route of administration.

Class of drugs		%	Route of administration
Vitamins	Vitamin C	25 %	Per os
	Vitamin A	25 %	
	Neurobion	50 %	
Gastrointestinal	Hepatoprotective – silymarine	50 %	Per os
	Procinetics – metoclopramide	50 %	I.V
Antifungal	Kanesten	33%	Local
	Ketoconazole	33%	
	Fluconazole	33%	Per os
Antiparasitic	Allopurinol	100%	Per os
Cancer Chemotherapy	Vincristine	100%	i.V
Cardiac	Diuretics furosemide	50%	s.c
	ACE inhibitors Enalapril	50%	Per os
CNS	Diazepam	25%	I.V
	Propofol	50%	I.V
	Fenobarbitol	25%	Peros

Table 3. Distribution of off label prescribed drugs according to pharmacologic class in cats

Class		%	Route of administration
Analgesic	*Meloxicam*	40	i.m
Glucocorticoids	Dexametasone	20	Topical
Antibiotic	Amoxicilin	30	Per os
	Sulfamthoxazole+ trimethoprim	10	

4. Discussion

The reasons all over the world why veterinarian frequently use "off-label" drugs from human medicine may be different: low price in, a human-approved drug may be significantly cheaper than a similar veterinary-approved product, making it a more affordable option for pet owners; the number of medications developed and approved specifically for animal use is far smaller than those available for humans; limited veterinary drugs, no medicines available for treatment of specific condition, many animal diseases do not have a corresponding approved animal drug, more suitable drug formulathe available animal drug may not come in a suitable strength or form for a particular patient. (Filipovic 2008, Holso et al. 2005, Escher et al. 2011, Rollin et al. 2002).

The most common reason for off label use of human drugs by Macedonian veterinaries is leak of availability of certain drugs i.e. drugs are registered for human use and are not registered for veterinary use in Macedonian market. A certain number of therapeutic agents required in small animal practice, particularly those used for infectious, cancer treatment, and analgesic indications, are registered for human use and are not available for the veterinarians. Beyond this regulatory limitation another reason for off label use of human drugs in veterinary medicine is economic reason or low price. Human formulations are frequently more affordable, more widely stocked in pharmacies, and available in multiple generic forms, making them a practical option for both veterinarians and pet owners.

Antibacterial drugs represent the most frequently used class of 'off label ' drugs in small animal practice in our country, and these data are similar to results from other countries in Europe (Tomanic et al. 2022, RoliTarillion et al.2025, Odensvik et al. 2001, Tarillion et

al.2025). This trend suggests that veterinarians in small animal practice across the region face similar therapeutic limitations.

Oral application of antibacterial drug amoxicillin–clavulanic acid (Amoksiklav®) was the most commonly prescribed off label drugs in our research in both dogs and cats, reflecting its broad-spectrum activity, safety profile, and low prices.

Topical antibacterial preparations were the veterinarian's choice for local treatment of bacterial infections. Topical-ocular and auricular application of antibacterial drugs (tobramicin, tyrotricin, ciprofloxacin) were frequently used. Most likely due to the limited availability of veterinary-specific topical agents for eye and ear infections.

Sulfonamides were choice of off label treatment of cystitis in dogs. Doxycycline continued to serve as the standard off-label treatment for *Ehrlichia canis* infections, reaffirming its well-documented efficacy and longstanding use in managing vector-borne diseases in dogs. Veterinarians in small animal practice, in order to provide appropriate therapy based on evidence-based medicine, are replacing the gap and lack of appropriate drugs from veterinary pharmaceutical market with off-label use of drugs from human medicine.

Tomanicet at al.(2021) reported that oral antimicrobials were the most commonly off label prescribed drugs for dogs in Serbia which is in agreement with our study. Our data shows that digestive issues are the most common condition for therapeutic use of off label antimicrobial drugs, which is in agreement with others studies (Gomez-Poveda and Moreno 2018, Tomanicet et al. 2021, Rantala et al, 2004) where digestive disorders where the most common condition for off label use of antimicrobial drugs in dogs. In our study, in cats, analgesic were the most common medications for off label use, and the main reason was the leak of *registered analgesic suitable for veterinary use in these species.*

In this use of human drugs in veterinary medicine, veterinarians should always determine the correlation between clinical necessity and potential risk, and always should be guided by foundational principle in medicine "*primum non nocere*". While human drugs may offer effective therapeutic alternatives, their pharmacokinetics, absorption, distribution metabolism, elimination and toxicity profiles are often different in certain animal species. Dogs and cats demonstrate significant interspecies variation in drug absorption, hepatic metabolism, and renal elimination (Court 2013, Davis 2013). Differences such as feline deficiencies in glucuronidation or breed-specific sensitivities in dogs (e.g., MDR1 mutations) heighten the risk of adverse reactions when human formulations are used without evidence-based dosing guidelines. Several studies have documented significant variation in prescribed doses, incomplete documentation, andunjustified use for off-label drugs, suggesting that veterinarians in clinical practice rely on their own individual experience rather than standardized protocols (Rentala et al.2004, Escher et al. 2011, Grave et al. 1992).

The widespread use of human antimicrobials in small animal medicine raises additional concerns related to antimicrobial resistance. Companion animals live in close contact with humans, facilitating potential bidirectional transfer of resistant bacteria. Off-label prescribing, particularly when involving critically important antimicrobials, may increase the risk for antimicrobial resistance if the therapy is not supported by culture and susceptibility testing, appropriate dosing, and treatment duration. While some studies have shown that veterinarians often rely on their own experience, others studies highlight increased awareness of antimicrobial resistance and conscientious use of antibiotics in small animal practice (Karagiannidou et al. 2020, Hardefeldt et al. 2022, Radford et al. 2015).A study in Norway has shown that 50% of antibacterial drugs used in dogs were off label from human medicines, while in Sweden this percentage was 20%. (Odensvik et al. 2001). These differences may be as a result of different regulations, differences in procedure for

registration of drugs in each country, different animal populations and different therapy choices for companion animals ((Odensvik et al. 2001, Hölsö et al. 2005, Tanaka et al. 2017).Guidance for specific indications in cats and dogs could contribute to greater legal certainty in small animal practice with regard to the justification of off-label use (Tarillion et al. 2025).

Consequently, there is a potential risk of transmission of resistant genes from companion animals to humans (Pomba et al. 2017, Schwarz et al. 2017), giving more reasons for veterinarians to be more careful with antibacterial drugs used in companion animals. Responsible off-label use of antibiotics is critical for minimizing the development of antimicrobial resistance, a significant public health concern. Use of antimicrobials should be addressed in the context of One Health Concept of the World Health Organisation (WHO). One Health involves the public health, veterinary, public health and environmental sectors. (WHO 2017). Ethically, veterinarians must balance their obligation to treat animals effectively with the responsibility to avoid harm.

5. CONCLUSION

In conclusion, the findings of this study indicate that in small animal veterinary practice in North Macedonia, the off-label use of human medicinal products, particularly antibacterial drugs, remains a widespread and routine clinical practice. This situation reflects the limited availability and limited registration of veterinary-licensed, as well as the need for veterinarians to use drugs intended for human use in order to manage a broad range of medical conditions in dogs and cats.

Clearer professional guidelines and better regulation are needed to provide veterinarians with clear and standardized protocols, thereby justifying the use of human drugs.

To ensure safer and more rational use of off label drugs in veterinary medicine more studies are needed. Future research should focus on collecting more evidence-based data, evaluating treatment outcomes, and identifying potential risks associated with off-label use of human drugs in small animal practice. These efforts should be complemented by the development of national recommendations and clinical guidelines that support veterinarians in making informed and responsible therapeutic choices.

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ACCESS TO JUSTICE IN ENVIRONMENTAL MATTERS: COMPARATIVE STUDY OF INDIA AND EU

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ABSTRACT

Introduction: *In environmental governance, access to justice is crucial to ensure accountability, public contribution and safeguards of rights. Both India and Europe have established legal systems to uphold environmental justice, but they do so within very different legal, cultural and constitutional frameworks. The Aarhus Convention dominates the European framework, although "Articles 21, 32 and 226 of the Indian Constitution" are based on judicial activism and constitutional foundations. This study examines the similarities, differences and lessons for improving access to justice between the judicial systems of India and Europe.*
Method: *The study adopts comparative legal analysis referring to international instrument's constitutional provisions and judicial decisions. Decisions of the "Indian Supreme Court and the National Green Tribunal (NGT)" are analyzed alongside decisions of the "European Court of Justice (ECJ) and European domestic courts."*
Result: *The Indian judiciary has given a wide interpretation to the right to a healthy environment under Article 21, thereby expanding "access to justice via PILs (PILs)." A special place for environmental disputes has also been bestowed by the NGT. On the other hand, Aarhus Convention guarantees that people and NGOs can challenge environmental decisions in Europe. Although the ECJ has upheld these rights, member countries continue to impose practical barriers such as cost and permanency requirements.*
Discussion: *While both countries support the right to access to justice, Europe places greater emphasis on procedural safeguards and conformity to international standards, while India relies more on "fundamental rights and judicial innovation." Europe offers organized but sometimes limited procedural channels, while India's PIL mechanism offers a comprehensive approach but risks overburdening the courts. Collectively, these models demonstrate different but complementary perspectives on environmental justice.*

Keywords: Environmental justice, PIL, Access to justice, Aarhus Convention

INTRODUCTION

"A collective body of rules and regulations, orders and statutes, constraints and allowances that are all concerned with the maintenance and protection of the natural environment of a country"
Black's Law Dictionary

In environmental matters, access to justice mentions to the public's right to fair and legitimate inquiry of decisions, actions, and omissions related to environmental matters. While this notion focuses on evaluating government officials' environmental decision-making, it also applies to opposing the actions and inactions of private individuals and business entities.*(Ebbesson 2002)*Environmental decision-making gives yield to considerations of distributive justice because it directly influences how several burdens and benefits are distributed among the individuals concerned, such as "*prioritizing access to natural resources over enduring the negative influence"* of harmful exploitation. However, in environmental issues, access to justice is not ponder to guarantee or mandate particular distributive outcomes in decision-making. Instead, it focuses on "*procedural arrangements and opportunities"*, that is, on access to institutions and mechanisms that, in principle, guarantee just distribution, just outcomes, and the rectification of unfair outcomes. In addition to these procedural and distributive "*facets of access to justice, it"* also bestows a means of correcting wrongs, that is, of wanting redress for unlawful acts and omissions. While such evolution and remedies are usually carried out by courts or other independent, fair legal bodies, administrative procedures may be enough in some circumstances, depending on the situation and the remedies required. (*Access to Justice in Environmental Matters European e-Justice Portal," n.d.*) Access to environmental justice and access to environmental information are closely connectednotion in the "*framework and terminology of international law and policy."*Public involvement in environmental issues and the availability of information on them are key. Access to justice is a means of correcting decisions, decision-making procedure, and mistake, while access to information is important for sufficient public involvement in environmental decision-making. ("*Convention On Access To Information, Public Participation In Decision-Making And Access To Justice In Environmental Matters"* 1998) This should be seen as a way to encourage environmental democracy, ensuring public involvement, "*transparency, governance, and control over environmental concerns*." International law is thus encroaching on issues that were once pondered domestic state concerns. During the 1970s, "*access to justice was broadly discussed in a number of national and comparative references"*, including environmental issues. It wasn't until the early 1990s that access to justice in environmental matters-previously outside the purview of human rights law-became a subject of international law.

Albeit"*Principle 23 of the 1982 United Nations Charter"* for Nature states that everybody has the right to pursue relief when their environment is harmed or degraded, the "*1992 United Nations Conference on Environment and Development (or "UNCED")"* was to show a more vital character in the progress of this area of law. In the "*Rio Declaration on Environment and Development*," over 150 states agreed on Principle 10.(Milieu Law & Policy Consulting 2024) The Rio Declaration shows the on large scale recognition that public involvement in environmental governance and access to information are directly connected to access to justice. "*Principle 10 of the Rio Declaration"* was not codified in any universally applicable treaty as a result of the 1992 UNCED. Ahead, it cannot be claimed that this principle shows universal international law. However, Principle 10 of the Rio Declaration has played a critical part in "*shaping political and legal debate in general,"*and hasinfluenced

both international law and state laws and policies. In 2020, Europe will face environmental issues of unprecedented magnitude and intensity. Europe has been a leader in industrialization and plays animportant role in influencing world events. Worldwide tendencies such as shifting population patterns and the worsening effects of climate alteration and it got worsevarious European problems today, and the rapid growth of technology is creating new threats and uncertainties.("Note From the Editors: World Health Organization Declares Novel Coronavirus (2019-nCoV) Sixth Public Health Emergency of International Concern" 2020)

It feels like that this progress will continue to exert greater pressure on the environment in the future. Understanding the current state, trends, and possibilities of the European environment needs a combined outlook recognizes the complicated drivers and impacts of ecological variation. Systemic solutions are needed to address immediate sustainability challenges and hurdles, yet current systems are characterized by path-dependence, which is related "*to the fact that system components"* (knowledge, technologies, infrastructures, etc.) have often evolved together over decades. ("European Environment Agency," n.d.) When the Commission publishes its annual report on the implementation of the "*Charter of Fundamental Rights"*in December 2023, it decided to highpoint the significance of access to impartiality and actual legal safeguard, which are secure by "*Articles 19 TEU and 47 of the Charter*."("2023 Report on Application of the Charter of Fundamental Rights in the EU, "n.d.) This decision is relied on the significance of these rights, which the Commission itself states are crucial to guarantee the full "*implementation of the Charter and of the EU regulations"* that uphold and defense the rights enshrined in the Charter. (Neframi 2012) Access to justice in environmental issues is aheadshielded by "*Article 9 of the Aarhus Convention,"* a varied contract to which the EU and its Member States are parties. In turn, this Convention binds "*the EU institutions and Member States"* as EU law.(Sharman 2023)
In an era of fast financial feast, cumulative industrialization, and urbanization, environmental justice issues may become secondary. Access to environmental justice is a critical component in ensuring fair and fair consequences for sustainable development in India.To address the procedural dimension of environmental justice, public policy measures have been developed "*in India, where average annual GDP growth between 2008 and 2018 was 7%"*(International Monetary Fund 2019). These measures include PIL, the National Green Tribunal (NGT), and "*green benches*" in state high courts (Government of India 2010). In keeping with its July forecast, the "*International Monetary Fund (IMF)"* has kept India's growth projection for FY2025 at 7%, and stressed that "pent-up demand" caused by the pandemic is easing as the economy becomes more efficient.(Sawhney 2024) Ahead, the government has had an official legislative need for environmental impact assessments (EIAs) since 1994, a method for anticipating, preventing, or mitigating the negative impacts of new development projects. (Paliwal 2006) Environmental Impact Assessment (EIA)can lead to solid progress when done properly, but if done hastily or inadequately, it can create friction between project proponents, influenced communities, and regulators. Rendering to "*Section 2(a) of the Environment Protection Act 1986",* the environment comprises water, air and land, as well as the interactions that exist amid these elements and other alive things, including human beings, plants, microorganisms and property.

PROBLEM STATEMENT

In environmental governance, access to justice is important because it bestows individuals and communities with the opportunity to protest infringement of environmental rights and hold public and private actors accountable. Despite the creation of innovative mechanisms such as the National Green Tribunal (NGT), India still faces problems such as "*access, delays, procedural intricacies,"*and low awareness among affected populations. On

the other hand, via the Aarhus Convention, "*the European Union (EU)"*has established a systematic structure for judicial review, public involvement, and access to information on environmental issues. However, even within the EU, there are still inequalities in how it is implemented athwart member states and issues of representation for individuals and non-governmental organizations. This absurdity raises a crucial issue: despite our shared international commitments to environmental safeguard, the legal systems of India and the EU differ enough, affecting both environmental outcomes and the exercise of rights. Comparative research is essential to identify areas of convergence, best practices, and shortcomings to improve legal measures and advance "*environmental justice in both countries*."

OBJECTIVE

The purpose of this study is to equivalence and judgmentally analyze the institutional structure, judicial procedures, and legal frameworks governing "*access to justice in environmental concerns"* in the European Union and India. The study focuses on how well citizens, civil society groups, and influenced communities are capable to access remedies for environmental damage, evaluate how well principles of international environmental law-such as the Aarhus Convention-are being followed,"*identifies best practices, weaknesses, and strengths*." The ultimate aim is to gain knowledge that can guide judicial innovations and policy changes, thereby reform participatory environmental governance and guarantee more skilled enforcement of environmental rights in both jurisdictions.

SIGNIFICANCE

In order to understand how various institutional, legal, and cultural references influence the implementation of environmental rights, it is crucial to compare India and the EU when examining "*access to justice in environmental matters"*.Through judicial innovations such as "*PIL (PIL) and the recognition of the right to a healthy environment as part of Article 21 of the Constitution,"*access to justice has expanded in India, permitting individuals and communities-specially marginalized groups-to challenge actions that harm the environment.

The European Union, on the other hand, has established a more organized framework based on Aarhus Convention and stress technical rights, including access to information, public involvement, and legal remedies. This is assisted by strong regulatory institutions. An analysis of the advantages and disadvantages of both strategies reveals that, while India is adaptable and proactive in "*encouraging environmental justice, the EU"*bestows a standardized, rules-based framework that reform legal certainty and compliance. In addition to encouraging inter-jurisdictional learning, this study helps create stronger international norms to safeguard environmental rights and increase"*democratic accountability in environmental governance."*

LITERATURE REVIEW

For this research study on Access To Justice In Environmental Matters: Comparative Study, thorough analysis of relevant scholarly works, theoretical perspectives, empirical investigations, and coverage assessments were part of the literature review process. The objectives of the literature review were to present a theoretical framework, highlight important paradigms and debates, and place the research in the context of current knowledge about environmental justice.

In article*"**Environmental Justice And Its Role In India's Legal Framework written by Sreyasa Dey, Disha Tiwari & Sagnik Roy Choudhury***" they discuss and draws awareness to severalfacets of Indian environmental justice studies. It examines theoretical frameworks such as "*distributive, procedural, and recognition justice"* and shows how these

perspectivesare helpful in analyzing environmental inequalities. This assessment explores the growth of India's environmental laws over time, thrown lighton main facets of such as the "*Forest Rights Act 2006,Environment Protection Act 1986, and the Wildlife Protection Act 1972,"* as well as their influence on sustainability and equity. It also checks how civil society, grassroots movements, and judicial interference-specifically, judicial activism and PIL, or PIL- have donated to the expansion of environmental rights.

In article "***Access to Justice in Environmental Matters in the EU Legal Order: The "Sectoral" Turn in Legislation and Its Pitfalls Mariolina Eliantonio and Justine Richelle"*** It focuses on how the Aarhus Convention safeguards the rights to contribution, knowledge, and legal recourse. It putts attention to scholarly discussions on the EU's incompatible and frequentlyconfined application of its Aarhus responsibilities, especially with regard to the legal status of individuals and NGOs in EU courts. Researchers showclash between the Convention's participatory principles and EU institutional frameworks, and highlight weaknesses in judicial supervision and implementation. The review also includes comparative observations of Member States' practices, showingconvertible levels of transparency in bestowing"*access to environmental justice."*

In article "***Environmental justice in India: a case study of environmental impact assessment, community engagement and PIL Ariane Dilay, Alan P. Diduck & Kirit Patel"*** Discusses specially from the purview of PIL community involvement, and "*environmental impact assessment (EIA)."*It highlights how research has praised the "*EIA framework as crucial regulatory tool, but also criticized its lax enforcement and limited capability to engage influenced populations*." PIL is a fateful means of accessing justice for underrepresented groups, and previous studies have emphasized the necessity of judicial activism and grassroots mobilization in shaping environmental governance. Researchers have also identified systemic disadvantages, such as lengthy procedures, a lack of openness, and a failure to in abundanceponder social justice issues when making environmental decisions.

In article ***"Access To Environmental Justice In India With Special Reference To National Green Tribunal: A Step In The Right Direction Gitanjali Nain Gill"*** Investigate the history of PIL(PIL) after the "*Bhopal tragedy, which expanded and unified rights under Article 21,"*but also suffered from disadvantages such as delays, inconsistencies, and judicial overreach, this article examines access to environmental justice in India. It pulls attention to how international agreements (such as the Rio Declaration and the Aarhus Convention) have influenced India's judicial reforms, especially the character of PIL in maintaining sustainable development notion such as "*polluter pays and precautionary measures."*The 2010 founding of the National Green Tribunal (NGT) has characterized as reformist step because it bestows specialized, speedy decisions for environmental cases, has broad jurisdiction, and has benches with various expertise.

GAPS IN KNOWLEDGE

Albeit the work of "***Shreyasa Dey, Disha Tiwari, and Sagnik Roy Chowdhury"***propose a detailed analysis of environmental justice in India, it centeredmainly on descriptive accounts of legislation, judicial activism, and civil society interference. It also detects the growth of crucial environmental laws and analyzes theoretical frameworks such as distributive, procedural, and recognition justice. Empirical research evaluating the actual impact of these laws and judicial actions in decreasing environmental inequalities on the ground is still required. There is also a lack of research assessing how existing legal frameworks adapt to changing environmental crises, as there has been little study of how environmental justice intersects with new problem such as urbanization, industrialization, and climate change.

Albeit"***Eliantonio and Richelle****"*examine how the EU has implemented the Aarhus Convention and point out the clash between "*participatory principles and EU institutional frameworks*," less is known about how sectoral laws influence the actual enforcement of rights to knowledge, involvement, and legal recourse as well as how judicial monitoringassist to resolve these clashes. This inequalitysignal that more exhaustive, international research is need to decide how EU-level dedication are translated into practical "*environmental justice on the ground."*

Although, "***Ariane Dilay, Alan P. Diduck & Kirit Patel***" PIL and environmental impact assessment (EIA) are crucial tools for moving forward"*environmental justice in India,"*but little is known about how EIA processes successfully unified social justice and community involvement, or how PIL result directly impact environmental governance at the local level. While existing research identifies procedural and regulatory lack, it does not properly examine how to address this shortage to obtain more just and inclusive environmental decision-making.

"Geetanjali Nain Gill"stress how PIL and the establishment of the NGT have move forward environmental justice in India, but there is little data available on how well the NGT has worked to trace the "*judicial overreach, delays, and inconsistencies"* that with traditional PIL. Becauseof the limited study of the association "*between international environmental standards and the operation"*of the NGT, there is also a shortage of information on how global principles are translated into practical environmental justice in India.

RESEARCH METHODOLOGY

When while doing secondary research for the paper "***Access to Justice in Environmental Matters: A Comparative Study,"*** a rigorous methodology was used to ensure in-depth coverage of "*relevant case studies, policy documents, legislation, and literature."*The methodology adopted for the secondary research included several key tasks.

DOCUMENT ANALYSIS: To perceive the criminal environment governing environmental issues in India, a diversity of "*prison documents, including laws, policies, rules, and authority regulations, were analyzed."*Obtaining relevant data and information need reviewing the websites of official authorities, criminal databases, and case law repositories.

CASE ANALYSIS: The selected case studies have been detailed researched to show how environmental justice notion can be executed within the legal frameworks of India and the UK. These case studies show real-life instances of environmental clatters, network fights, and illegal actions, bestowingpriceless visions into the shades and complications of environmental fairness concerns in the UK and India.

POLICY REVIEW: To evaluate the degree of unification of environmental justice concerns into "*policy frameworks, national and state-level environmental guidelines, movement scheme, and steps have been examined."*In order to perceive how coverage objectives, implementation strategies, and stakeholder engagement methods influence social justice and environmental governance, this needs research.

COMPARITIVE ANALYSIS: To identify training findings, forward-thinking procedures, and possible areas for growth within India's legal system, a comparative comparison with international legal frameworks and "*best practices in environmental justice were conducted*." This comparative perspective identified chances for cross-fertilization of ideas and perspective and helped place India's story in a larger global affair.

HISTORICAL DEVELOPMENT OF ENVIRONMENT LAW IN INDIA

Two distinct phases can be seen in the advancement of Indian environmental law:

- **Prior to 1972,** India's progress was mostly based on a mixture of illegal and tort laws, water and forest regulations, and specific legislation to tackle environmental safeguards issues. Continuous this generation, it is observable that Indian environmental law made relatively little growth. (Boutabouna and Achour 2025)
- **The period after 1972** saw valuable "*growth in international environmental law",* consistent with the conclusions of the Stockholm Conference. Next the Stockholm Conference, environmental protection care attracted international attention, and India was no exception.

The 1972 Stockholm Conference on Human Environment and Development at the UN directly encourage the creation of "*Stockholm Declaration on the Human Environment. The 1948 Universal Declaration of Human Rights"*also has equal status with this Declaration, reflecting its preponderance in the field of environmental law. When the then Indian Prime Minister, Mrs. Indira Gandhi, attended the Stockholm Conference, she was profoundly impressed by the debates, the concerns raised, and the growth made. This spur led to quick reforms in India's environmental policy immediately following the Stockholm Conference. (The Lawway With Lawyers Journal 2025)

THE 42ND AMENDMENT ACT TO CONSTITUTION OF INDIA

The 42nd Amendment introduced serious changes to the Constitution of India, especially with regard to environmental law. It "*placed a sodality accountability"* on the state and its citizens for environmental safeguards and conservation. "*Article 48A, supplementary to the Directive Principles of State Policy"*of the Constitution of Indian,required the state to safeguard the country's forests and animals, as well as to improve the environment. The addition of Article 51A of the Constitution of India it imposed ten mandatory liabilities on citizens. These duties were made in recognition of the fact that citizens are entitled to numerous fundamental rights along with their citizenship. "*These fundamental duties continuously remind citizens"* though the Constitution give them clear fundamental rights, it also enforces precise duties on them to fulfill in order to be receptive citizens. This recognizes the fundamental relationship between rights and duty. "*Article 51A(g) needs citizens to show grace towards all living creatures"*and to defend and upsurge the natural environment, as well as "*forests, lakes, rivers, and wildlife"*. Article 21 of theConstitution of Indiabestows the fundamental right to live in a "*pollution-free environment and to have access to clean water and air."*Albeit the right to personal liberty and life were guaranteed by the Constitution, their numerousamplitudesslowly became clear as a result of court decisions and research. (Razzaque et al. (2015))

THE INDIAN JUDICIARY AND PIL

India has purpose to create its laws and policies more exhaustive and rigid, particularly after the 1984 Bhopal industrial disaster. (Divan and Rosencranz 2022) Albeit, ineffective enforcement of environmental regulations has been caused by inconsistencies and weaknesses in institutional procedure. This failure can be held responsible to numerous factors, including "*personal gain, multi-level corruption, political intervention or indifference, and negligence or poor performance of enforcement officials."* As a result, in the 1980s, the Indian judiciary's responsibility to "*ascertain the enforcement of rights ahead the scope of constitutional rights"*led to the origin of PIL(PIL).(Gill 2012) PIL was a valuable addition to traditional common law remedies, With procedures and remedies fixed by judges, it is a people-centered, detailedperspective that encourage access to justice. The

idea was that people who have historically been denied "*access to the courts due to caste, poverty, ignorance, isolation, or fear"*would be able to use the law to safeguard their fundamental human rights, either directly or via a court-recognized friend.(Sathe, S.P. 2002).
The use of PIL in the "*explanation of three constitutional provisionsof the Indian Constitution: Articles 48A, 51A(g), and 21*" has enoughtransformed India's environmental landscape. Article 48A, a "*Directive Principle of State Policy*," needs the State to conserve the nation's forests and wildlife, as well as to secure and advance the environment. Article 51A(g) needs every citizen to have grace for all alive creatures and to defense and advance the natural environment, including forests, lakes, rivers, and wildlife. The right to life is definite as a fundamental right by Article 21. "*Article 21 of the Indian Constitution"*bestows the rationale for the integration of environmental protection and human rights. (T Damodar Rao v The Special Officer, Municipal Corporation of Hyderabad AIR 1987 AP 171, 181) *Justice Bhagwati said in* ***Francis Corley v. Delhi****:"We hold that the right to human dignity involves the right to the basic necessities of life, such as adequate food, clothing and a roof over one's head, as well as the ability to read, write and express oneself in various ways*." (Francis Corley v. Delhi, AIR 1981 SC 746)

In Virendra Gaur v. State of Haryana, "*the Court held that a healthy environment is one free from environmental pollution and declared that the right to life is safeguarded as a fundamental right under Article 21."*The enjoyment of life, which involve the "*right to live with human dignity,"*includes, among other things, ecological balance, cleanliness, and safeguarded and security of the environment, free from air and water pollution, which are necessity for the enjoyment of life. Environmental pollution results from any adverse activities or actions. Pollution of air, water, environment, etc., is pondered"*an infringement of Article 21."***(**Virendra Gaur v. State of Haryana (1995) 2 SCC 577)

M C Mehta v Union of India it is vital that, the Supreme Court has applied Articles 48A, 51A(g), and 21 as supplement to each other and, where suitable, has issued important directions on environmental issues. Albeit termed a "*duty*," the*"duty imposed on the State under Article 48A"*must be interpreted as a right similar to that granted to citizens under Article 51A(g).as a result, the right granted under "*Article 21 must be interpreted to fall within its scope*." (M C Mehta v Union of India (1998) 9 SCC 589)

In the case of **Mumbai Kamgar Sabha v. Abulbhai Faizullabhai.** "*The Court held that procedural rules are slaves of justice, not its mistresses, and that lack of fair play is the spirit in which the courts should view (procedural) deviations."*(Mumbai Kamgar Sabha v. Abulbhai Faizullabhai AIR 1976 SC 1455)

Two mechanisms have been used to change locus standi: "*representative and civil standing*." With representative standing, any person acting in good faith can file a claim against human rights infringement on behalf of victims who, "*due to poverty, disability, or social or economic impairment*," are unable to "*reached to a court for judicial enforcement of their fundamental rights."*Civil standing permits for the solving of a public grievance; it influences society as a whole, rather than just one individual.

Both **A.P. Pollution Control Board v. Prof. M.V. Naidu and S. Jagannath v. Union of India** agreed on the necessity of these expert panels in advising the Court on the "*course of action when examining scientific issues."*(A.P. Pollution Control Board v. Prof. M.V. Naidu AIR 1999 SC 812 and S. Jagannath v. Union of India 1997 (2)SCC87)

The lax procedural norms of PIL are remunerative for ascertaining environmental justice but they are not liberated to external criticism. Critics believe that the courts are deemed the same duties that have historically been exhibited by the government and Parliament. (Narmada Bachao Andolan v Union of India (2000) 10 SCC 664) The Supreme Court of India, which "*has been accused of being an excessively active legislative body"*viaPIL, is a key example of the broader jurisprudential doubt of the legitimacy of

judicial lawmaking.The Court is now open to forum shopping, permitting for more personal justice under the law rather than institutional adjudication, due to the "*relaxation of the standing rule."*Some judges, seeking public attention, favor PIL in their courts, while others have earned the nickname *"green judges, advocates for the poor, or progressives."*(Baxi, U. 1983).

NATIONAL GREEN TRIBAL NEW FORUM

"The Law Commission of India's recommendations,' together with the previously listed matters of pendency and delays in PIL, led to the establishment of the National Green Tribunal. The Law Commission of India firmly supported the establishment of environmental courts in its "***186th Report (2003) on the proposal for the establishment of environmental courts."(Law Commission of India 2003)***The Supreme Court of India's judgmenthelping the establishment of environmental courts had an influence on the "*Law Commission of India*." In its verdict in the "***A.P. Pollution Control Board v. M.V. Naidu case*"** the Supreme Court of India stated that the Law Commission could examine the matter because it was crucial to establish environmental courts that would gain from the expert opinions of environmental scientists and other technically deserving individuals as part of the legal system. (*A.P. Pollution Control Board v. M.V. Naidu case* 1999(2) SCC 718 and 2001(2)SCC 62) The Supreme Court of India, in "***M.C. Mehta v. Union of India,"***stated that given the expertise need for such adjudication, it may be desired to establish regional environmental courts which includes of a professional judge and two experts. This is because of the adjudication procedure for cases involving environmental pollution, ecological destruction, and "*clash over national resources is speedily rapid and involves the analysis and growth of scientific and technical data."*Appeals against the Environmental Court's verdict will be permitted in this court. (M.C. Mehta v. Union of IndiaAIR 1987 SC 965) Experience has depicted that cases started in regular criminal courts under the Water Act, Air Act, and Environment Act are never concluded, either dueto the courts heavy workload or because those handling these cases do not fully understand the necessity of environmental issues. Ahead, companies immediately challenge any orders issued by "*authorities under the Water, Air, or Environment Acts in court,"* These cases frequently take years to resolve. Interim orders are frequent issued mid-stream, leaving officials unable to ascertain that their instruction is being followed. All of this points to the exigency to establish environmental courts, which should be empowered to "*try any civil or criminal case connected to the environment."*These courts should be employed by judicial officers and legally deserving individuals, and should have the power to conduct summary proceedings. Of course, before taking any action, the matter should be detailed researched and analyzed from every angle.

THE AARHUS CONVENTION IN EU LAW

More than two decennary after its ratification in 1998, the Aarhus Convention continues to work as a leading model for executing the idea of environmental democracy, incarnated in "*Principle 10 of the Rio Declaration on Environment and Development."*When the Aarhus Convention entered into force in 2001, former UN Secretary-General Kofi Annan stated it as the most progressive environmental democracy step ever undertaken under UN sponsorship. States and regional economic integration organizations had the option of ratifying "*(admitting, approving, or acceding to) the Convention."(Odermatt 2017)* The progress of environmental rights reached a turning point with the ratification of the Aarhus Convention. This event tagged a historic turning point and anunprecedented example of the global community's attempts to reform environmental protection. The Convention does not establish a "*substantive right to a clean and/or safe environment*." Rather, it concentrates on the procedural outlook of claiming the right to a habitable environment appropriate for one's health and well-being.

Like its predecessors, "*the EU's Seventh Environmental Action Programme (7th EAP)"* stresses the necessity of public The foundational stone of the European Union's environmental policy is the Environmental Action Programme (EAP participation in environmental issues. "*The Dublin European Council in 1990"* concentrated that Member States must fully adopt and execute Community environmental regulations for them to be emphatic. The European Commission has accepted these lackness and has repeatedly stressed the need of public involvement in the execution of environmental law.(Jans, Vedder, and Europa Law Publishing 2008) EU environmental law wantstosecure the human health as well as to protect and reform the environment. The Aarhus Convention's goals are compatible with the purpose of the EU's environmental policy, as said in "*Article 174 of the TFEU.By ratifying the Aarhus Convention*," the EU has showed its devotion globally to ascertainingwide access rights and appropriate public involvement in environmental issues. "*When these rights and duty are not executed equally across the EU,"*current citizens will not be eligible to take full benefits of EU environmental laws, and advancement towards the EU's environmental objective may be obstruction caused. ("Decision- 2005/370–EN-EUR-Lex," n.d.)

No doubt that the Convention isa primalingredient of the EU's legal system and, in congruence with "*Article 216(2) of the TFEU*," is obligatory on both the EU institutions and its Member States.(*Case C-470/16 North East Pylon Pressure Campaign Limited and Maura Sheehy v An Bord Pleanala and Others EU:C:2018:185, para. 46*) Established jurisprudence holds that, as for as these conditions are within the Union's jurisdiction, mixed agreements "*concluded by the EU, its Member States and non-Member States"* have the same place in the Union's legal system as agreements considerably of the EU.(Meryem Demirel v Stadt Schwäbisch Gmünd (C-12/86, EU:C:1987:400, 9)

A detailed laws has already been adopted by the European Union; these laws are continuously changing and enforce to "*public authorities in Member States as well as to the EU's own organizations and bodies."*To achieve the promises of Aarhus, not only has judicial safeguard been amended, but information access and involvement procedures have also been improved at the national and EU levels. Some, mostly older, environmental instructions needed to be modified to involve provisions for public participation. "*Directive 2001/42/EC concerning the evaluation of the influence of few plans and programs on the environment and ("EUR-Lex-L:2001:197:TOC- EN-EUR-Lex," n.d.) Directive 2000/60/EC establishing a framework for Community action in the field of water policy were already adopted in congruence with the Aarhus Convention."("EUR-Lex-L:2000:327:TOC-EN-EUR-Lex." N.d.)* In addition to reviewing the"*Directives 85/337/EEC and 96/61/EC*," the Commission offer a new instruction on public participation in the formulation of environmental plans and programmes. ("Directive-2003/35-EN-EUR-Lex," n.d.)

ART. 9(3) OF THE AARHUS CONVENTION AND ACCESS TO JUSTICE

*"Article 9(3) of the Aarhus Convention"*command that public authorities and private individuals have access to scrutinyprocess for their actions and inactions connected to national environmental law. In pursuance to this provision, the general public, those "*grouped as one or more natural or legal persons under Article 2(4) of the Convention,"*as well as their associations, organizations, or groups following national laws or customs, must have access to these scrutiny process.(Eliantonio 2015) So, the national law must determine what formulates a member of the public. Albeit, in pursuance to the "*Aarhus Convention Compliance Committee (ACCC)"*,these norms should not be excessiverigid.(ACCC/C/2005/11Belgium) In pursuance to the ACCC, "*Article 9(3) cannot be used to successfully inhibit"* almost all members of the public from opposing their actions and omissions, even if the parties are not needed to establish an "*actio popularis system*." The

Convention's general objective is to ascertainwide access to justice, which should guide the parties' discretion about jurisdiction. (ACCC/C/2008/32 (Part I) European Union) Since the existing national rules influence the "*execution of access to justice laws, the role of national legislation"* is elucidated. An administrative body or court may also haul out the scrutiny required by Article 9(3).(UNITED NATIONS 2000) Article 9, which deals with environmental infringement of domestic law, bestowsnumerous options for scrutiny, In this case, the ACCC has permitted the public to report infringement of environmental law without any reasonable suspicion. ("Case No ACCC/C/2006/18 (Denmark)," n.d.) Ahead, as stated in Article 9(3), the scope of environmental law should "*involve both the procedural and substantive validity"* of a decision, not just procedural rights. Finally, it should be well-known that Article 9(3) covers process for contesting actions taken by both public and private entities.

ART. 9(3) AND THE EU LEGAL SYSTEM: A STORY OF UNEASY BEDFELLOWS

When signing the Aarhus Convention, the EU elucidate that it would cover both national public authorities and its own institutions. It also mentioned that Member States would be accountable for ascertaining that the duty arising from Article 9(3) are adherence with, until EU law fitted provisions for their execution is finalized.("Study on EU Implementation of the Aarhus Convention in the Area of Access to Justice in Environmental Matters"2018) As of now, to date, no particular legislative instrument has been enacted to relocate Article 9(3) in the same manner as Articles 9(1) and (2) have been relocate with regard to domestic access to justice. Still, it should be known that the "*access to justice provisions found in some EU legal instruments"*tumble within the scope of Article 9(3) may be pondered to have been relocate into those instruments in a de facto means. Following the failure of the "*offer for a Directive on Access to Justice in Environmental Matters,"*the European Commission acknowledged the necessity to successfully and fully incorporate Article 9(3) of the Aarhus Convention into EU law and began pondering the subject. ("Aarhus" 2021b) At that time, a "*Darpo analysis concluded that national measures tumble under Article 9(3*)" were inconsistent and various, this shows a clear exigency for full legislative adaptation of this provision. (Darpo 2013) Nevertheless, this result, the Commission decided to purport a soft law instrument entitled *"Notice on Access to Justice in Environmental Matters" in* 2017. (EUR-Lex-52017XC0818(02)-EN-EUR-Lex," n.d.) The CJEU has issued numerouscrucial judgments over the past few years that have elucidate the scope of application of Article 9(3), and in the LZI case, the Court concluded that albeit litigants before national courts cannot depend directly on Article 9(3),(Lesoochranarske zoskupenie VLK v Ministerstvo zivotneho**)** they still have a duty to explain procedural rules in a means that is consistent with the objective of Article 9(3). The case led to a number of verdicts,involving one that held that Article 9(3) could provide NGOs the right to make accusation of"*infringement of the Water Framework Directive*,"(Protect Natur-. Arten- und Landschaftsschutz Umweltorganisation v Bezirkshauptmannschaft Gmind) forcing national authorities to modify action plans designed to decrease nitrate pollution.("Court of Justice Confirms Standing of Individuals to Challenge Nitrate Action Programmes" 2025).

THE PROPOSAL FOR A NEW DIRECTIVE ON ACCESS TO JUSTICE

Albeit the authors EU Treaties passed both "*Article 19(1) TEU and Article 263(4) TFEU*," which need national courts to bestowsappropriate measures to guarantee an influential judicial remedy, there is currently no more detailedarrangement on access to justice that covers all environmental cases and "*translates the needs of Article 9(3)."*(*Leijon 2020)*The European Commission's 2003 motion set out a set of leastdemand for legal status, permitting for the safeguards of national legal status systems. These basic norms were

intended to inhibitcondition of imparity between national authorities and economic operators by encouragingconformity to the "*Aarhus Convention and coordination laws across Member States*." How be it, this idea did not receive enoughhelp from the legislatures of Member States in the Council. The Commission eventually extracted this motion in 2014. Merely when environmental NGOs meet distinctdemand can Member States grant them status under the "*Aarhus Convention and EU law. EU Member"* States have numerous traditions. While some bestows broad access to justice, such as "*actio popularis,"*which permits everyone to act in environmental advocacy, others take a more limited perspective.

Meanwhile the 1990s, national courts have been consulting the Court of law on how to handle numerous"*guarantees of access to justice. In the well-known "Slovak Bears (VLK) case,"*the Court consider that a particular issue, which had not yet come inside the horizon of EU law, tumble within the purview of EU law, bestows it administered by contractamong the EU and its Member States and connect to the area usually covered. Ahead, the Court upheld the necessity that national courts enforce the Aarhus Convention when interpreting provisions connected to access to justice.(Lesoochranarske zoskupenie VLK v Ministerstvo zivotneho**)** A 2012 study investigated four feasible action alternatives. The first alternative was to pass a new instruction that shows the "*EU Court of Justice's legal framework"* and Member Stateslegal framework about the jurisdiction of environmental NGOs. The second alternative was to reiterate the Commission's priorproposal. Third, use soft law tools-possibly increased by guidelines-to stimulatecollaborationamong national courts. Lastly, it was endorsed that the violationsprocess be used as a means to stimulateconformity to the Court's legal framework. As per the 7th EAP's examination of "*access to justice in environmental issues"* crucialhurdles still exist in numerous Member States, and onward information propound that more work requires to be done at Member State level. With respect to all areas of EU environmental law, it apparent clear that a new instructionunderlining the necessity for emphatic and "*proficient access to national courts would assist over-simplify access to justice"* at the national level and stimulatecollaboration and communication between national authorities and courts.(EUROPEAN COMMISSION 2019) "*The Directive on Access to Justice in Environmental issues"*will ascertain a integrated system of access to justice in all Member States and equal rights for all EU citizens.

COMPARTIVE STUDY OF EU'S AND INDIA'S APPROACH

EU's international baseline is Aarhus convention and EU's law which creates baseline for parties to bestows access to information, involvement and access to justice in environmental matters. The access to revies procedures governs under article 9. The Aarhus convention was incorporated by EU in its union law and also the regulation enforces some convention rule to institutions of EU. Albeit the EU faced with criticism and results of partial non-compliance with article 9(3) & (4). While on other hand the architecture of India's access to justice rests on Indian Constitution (Article 21 Right to Life), the broader Doctrine of PIL (PIL) by the Supreme Court of India and also the National Green Tribunal which is statutory specialized body or forum. Which is created by National Green Tribunal Act 2010 which bestows prompt and effective ruling on environmental matters. (Gill 2018)

As per the article 9 of Aarhus convention it requires that the members of public with enough interest or those keep impairment of right be capable to challenge environmental verdict. EU law objective to bestows relatively wide standing, but in practice standing rule distinct across member states and EU institutions, compliance has been questioned, specially regarding the review of administrative omission and private actor related decisions. While in India courts have generous locus standi because of PIL reason. NGOs, Individuals, and even associations, may reach to courts on behalf of public interest. The NGT allow the petition from aggrieved person but use flexibility influenced by Supreme Court Jurisprudence.

The members of EU differ on court fees, trial standing, and evidence rules, and cross border execution and complication of environmental science that can create procedural hurdles. The EU recognizes the disparity in outcomes of access to justice across member states and there is active debate on uniform minimum procedural guarantees. (Halleux et al. 2021) the low cost PIL procedures, statutory assistance for the expert testimony in the NGT, and SUO MOTO power of NGT and courts to remove procedural hurdles all contribute to procedural access in India.

EMPIRICAL STUDY ON IMPLEMENTATION OF ENVIRONMENTAL LAWS

- **2024 ENVIRONMENTAL PERFORMANCE INDEX (EPI) SCORES- TOP EU COUNTRIES AND INDIA**

COUNTRY	GLOBAL RANK	EPI SCORE	10-YEAR CHANGE
ESTONIA	1	75.7	+17.6
LUXEMBOURG	2	75.1	+4.2
GERMANY	3	74.5	+4.6
FINLAND	4	73.8	+8.3
UNITED KINGDOM	5	72.6	+2.1
INDIA	176	27.6	+4.7

TABLE 1 (EPI,2024)

TABLE 1 Shows that India's score of 27.6, which places it at 176th, is in blunt difference to top EU countries, which scored between 72.6 and 75.7 in the "*Environmental Performance Index 2024.*" Since India fights with applying and imposing its laws, analysis proposes that the EU's Aarhus-based procedural outline delivers improved environmental consequences than India's rights-based method.

- **SINCE 2020-2025 PENDING OF CASES IN NATIONAL GREEN TRIBUNAL**

BENCH	PENDINGCASES
PRINCIPAL (DELHI)	1939
WESTERN (PUNE)	1933
SOUTHERN (CHENNAI)	846
EASTERN (KOLKATA)	411
CENTRAL (BHOPAL)	320
TOTAL	5,449

TABLE 2 (Tandon, 2025)

TABLE 2 Shows that By 71% of work still unfinished at the Delhi and Pune court sites, the "*National Green Tribunal of India has over 5,449 pending cases*." A main inadequacy of the Indian system is that it permits judges to create new legal defenses without bestowing the essential resources. So, the decisions on environmental cases are slower than in the EU Aarhus-based system.

- **ENVIRONMENTAL LAW VIOLATION PROCEEDINGS IN EU TILL 2025**

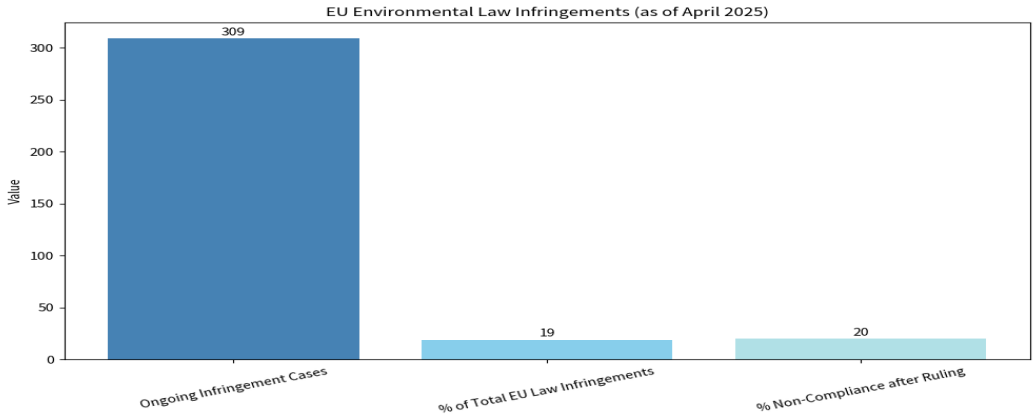

TABLE 3 (ClientEarth, 2025)

TABLE 3 Shows that Owing to the sustained problems confronted by member states in satisfying their environmental promises, the EU has 309 cases of environmental infringement, on behalf of 19% of the total. Compared to India's domestic framework, the European Commission-CJEU enforcement system bestows better observation and responsibility.

Finally Bestowing to the study, India and the European Union have diverse environmental systems that can use cross-system learning to progress their values for environmental justice and defense.

CONCLUSION

The EU and the Aarhus Convention have advanced and robust each other over time.Various accounts of the connectionamong"*EU law and the Convention*," especially the double standards adopted by EU authorities in this regard, have been published in the scholarly literature. The current state of EU law regarding "*access to justice in environmental"* concerns is somewhat complicated. The need arising from "*Article 9(3) of the Convention"* is not fully covered by EU legislative instruments currently in effect. The "*prognosis for the European environment is colorless,"*albeit EU environmental legislation has largely been successful, as SOER 2020 exhibit. When pondering the detailedfacets and complementary policy aims of the Seventh EAP, it becomes clear that "*the EU is not doing adequate to address environmental issues*." To fully advantage from environmental legislation, its execution is necessary. The absence of legal standing of private individuals beforehand the "*Court of Justice remains an ingredient of the EU's democratic loss*." This shortfall must be addressed by the Court of Justice, and the execution of a new Instruction on Access to Justice could assist governments raise standards for environmental policies and steps.

The complicated"*historical, cultural, social, and political reasons"* that impacts India's stand on human rights and environmental safety are depicted in the country's environmental justice movement. Pioneering environmental technologies crucial to "*traditional Indian lifestyles, such as sustainable agriculture and forest conservation"*, were made possible by this perspective. The advent of environmental justice in India depicts the country's transition from traditional to present day environmental governance. Albeit India

has made importantadvancement in environmental safety, issues such as pollution, deforestation, and climate change remain speaking these issues will need continued labors to reform environmental laws, encourage public involvement, and advance sustainable progress. A crucial step in encouraging procedural justice would be to bestows more possibilities for "*meaningful public involvement, such as information sharing, early community involvement in decision-making, and opinion of community desires.*"

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AI IN LITERATURE TEACHING: EXPLORING THE TRANSFORMATIVE POTENTIAL OF COMMERCIAL AI MODELS

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ABSTRACT

Introduction*: Artificial intelligence (AI) has completely transformed our world, fundamentally changing many areas of our daily lives. While natural language processing (NLP) technologies have become part of our day-to-day live, one of the sectors most significantly affected appears to be education. However, one area that remains underexplored is AI in pedagogical stylistics – i.e., the practical use of AI models in teaching literature within the English language classroom.*
Methods*: Recognizing a research gap, this qualitative paper explores how teachers can incorporate AI into pre-, during-, and post-reading activities. Drawing on existing literature and personal experience with AI use, the study proposes practical applications and activity designs, with a focus on instructional integration of AI.*
Results*: The paper proposes a series of practical AI-based activities designed to strengthen students' EFL (English as a Foreign Language) skills while leveraging the immense potential of these technologies in language and literature education.*
Discussion*: By addressing the gap in AI's role in pedagogical stylistics, the paper emphasizes AI's potential to improve engagement, comprehension, and critical thinking in literature-based EFL instruction.*

Keywords: Artificial Intelligence (AI), ChatGPT, Pedagogical Stylistics, AI in Education

1. Introduction

Stylistics has always been seen as problematic to define as it is often found *"sitting uncomfortably on the fence between the linguistic and the literary – a bit uneasy within either domain"* (Watson & Zyngier, 2007). Traditionally, stylistics helps both students and scholars understand how language "works" within literary texts. It does so by detailing the stylistic choices that contribute to meaning, tone, and overall impact on the reader. Pedagogical stylistics, a sort of a subset of this field, focuses on using stylistic analysis within different

educational settings in order to help students better understand both literature, as well as language.

Historically, this approach has relied on human-led methods of analysis and human-led teaching. Yet, with the introduction of mainstream advanced artificial intelligence (AI), and models such as ChatGPT, Gemini, Copilot etc. new opportunities have emerged.

1.1. Stylistics, Language, and Literature – Introductory notions

Stylistics, a field within applied linguistics, studies and interprets various kinds of texts or spoken language by examining their linguistic and tonal characteristics. It focuses on style as a distinct form of language shaped by individual speakers or specific contexts.

In the broadest sense of the word, stylistics is the science of language style (Verdonk, 2002). Its focus is on the way language varies, influenced by certain factors such as context, intent, author and period. Also, stylistics is defined as the linguistics of literature (Freeman, 1981). In other words, stylistics is a science that studies expressive means and possibilities of language, as well as their realization in speech. Although, seemingly, the definition seems simple, stylistics is not easy to define, as, according to Galperin (1977), it is determined by the several concepts associated with style itself – style as deviation, style as a choice, style as a distinct personality etc. – concepts that still serve as the basis of new scientific insights in this field.

As a discipline, stylistics serves as a bridge between literary criticism and linguistics. It does not operate as an independent domain but rather helps us better understand several disciplines: literature, journalism, linguistic phenomena, etc. Stylistics can be divided into two main branches: literary stylistics and linguistic stylistics, the latter of which also includes the study of functional styles (Widdowson, 1975; Simpson, 2004; Betti, 2021). As such, stylistics is extensively studied. One particular area of interest is pedagogical stylistics.

1.2. The Basic Tenets of Pedagogical Stylistics

Pedagogical stylistics functions within the wider framework of literary linguistics, with specific focus on teaching and the educational context, in general. Thus, as a separate entity, pedagogical stylistics aims to help foster better understanding of both literature and linguistic features. "Pedagogical stylistics promotes looking *at* language rather than *through* it" (Zyngier & Watson, 2022). This approach encourages students to engage with language in a much more tangible way and discover how stylistics can help shape it into different literary forms. According to the authors (Zyngier & Watson, 2022), pedagogical stylistics can also be a lens that can, in a way, level the playing field for both native and non-native speakers as both groups can learn important information to do with the way language is used mostly through literature.

This discipline, therefore, is a link between the subjects of English language and English literature, among else, and the disciplines of linguistics and literary criticism (Widdowson, 2013). According to Widdowson (p. 21), while the literary critic is primarily concerned with the meanings codes convey, the linguist solely focuses on the codes themselves. Both hold their merit, yet, it is only the one that studies stylistics, and by extension, pedagogical stylistics, that can fully understand how literature exemplifies the language system and breathes new life into it. In a similar manner, Gheni (2020, p. 62), states that *"pedagogical stylistics has two aspects: the first one covers the pedagogical account of stylistics for teaching the features of the language of literature, and the other includes the role of stylistics in teaching of English language through literature"*.

It is important to note, in this regard, that the term *pedagogical stylistics* is not to be used interchangeably with the term *pedagogy of stylistics*. The latter refers to the study of how to teach stylistics in particular, while the former refers to the application of stylistic

techniques in teaching – both in teaching stylistics but also in teaching other language- or literature-related content (Burke et al., 2012, p.137).

Moreover, pedagogical stylistics seems to prioritize the "foregrounding" effect of the language of literature. Foregrounding, as defined by Leech and Short (2007), is best seen in language patterns that are different from the norms. This can help draw readers' attention to stylistic elements like sound, rhythm or imagery. "Foregrounding" as a concept is crucial for stylistics, because it helps students recognize how deviations from the established rules in literary texts can have different emotional and cognitive effects. This concept, according to Zyngier (2001) can be particularly useful for non-native speakers.

But all students – non-native and native speakers alike – can benefit from stylistic analysis as it holds great pedagogical value (Burke, 2010). According to the author, pedagogical stylistics can improve literary awareness, and can be adapted to fit a wide range of classroom settings. Burke (2010) argues that by engaging with literary texts through a stylistic lens, students can improve their overall language proficiency, as well as their critical thinking skills, and even cultural awareness. This would help them acquire skills to both appreciate the aesthetics of language, as well as its practical use.

2. Review of Related Studies

As mentioned above, pedagogical stylistics relies on stylistic analysis in teaching literature and language. Thus, it aims to enhance students' understanding and language acquisition (Burke et al., 2012). It focuses on interactive classroom activities that raise awareness of language use in texts (Clark, 2007). Worldwide, research has shown that pedagogical stylistics can improve second or foreign language proficiency, build language awareness, and develop academic skills (Fogal, 2015). In the context of teaching English as a Foreign Language (EFL), pedagogical stylistics has been found to be effective in promoting language skills through literary texts, particularly poetry (Gheni, 2020). Studies have demonstrated that this approach improves students' literary intuition, motivation, and linguistic knowledge through pre-, during, and post-reading activities (Novak & Gowin, 1984; Ren & Wang, 2018; Daniels & Zemelman, 2004; Gheni, 2020 etc.). The British Council's Guide to Reading and Writing (2015, recognizing previous findings. also advocates for pre-, while-, and after-reading activities that support learners in reading full texts. Despite these insights, the field of pedagogical stylistics has been criticized for relying too heavily on self-interpretation rather than empirical support (Fogal, 2015).

Though papers that focus on pedagogical stylistics, in particular, in English, are few and far between, stylistics, and by extension, the implementation of literature and stylistics in the language classroom, have been extensively studied. Incorporating literature into language classrooms has historically been acknowledged as a powerful method to improve language proficiency, enrich cultural awareness, and promote critical thinking (Frantzen, 2001; Mart, 2018; Shepin, 2019, etc.). Henning (1993, p. 24), one of the pioneers in the field, advocates for using literature in the language classroom, stating that by doing so, *"students can develop a full range of linguistic and cognitive skills, cultural knowledge and sensitivity"*.

Chen (2018), more recently, emphasizes that integrating stylistics-based activities into an extensive reading program can significantly improve language learning, with students themselves reporting progress. According to him, activities that focus on identifying language features and structures, based on Willis's (1996) task-based methodology, helped enhance learners' awareness of the language used in the texts. Similarly, Jones (2019) notes improvements in spoken skills, along with more evident progress in literacy, after implementing tasks centered around literary texts. Additionally, Boers (2000), and Boers and Lindstromberg (2008) emphasize the importance of implementing stylistic features – such as idioms, metaphors, proverbs, and fixed expressions – in foreign language learning and

teaching, claiming that they improve students' language acquisition and overall language skills.

Despite the challenges of implementing literature into the language classroom – challenges such as too complex texts or students' lack of cultural understanding – research shows that the benefits of implementing literature in the language classroom far outweigh the disadvantages, and one interesting area that can be explored is the use of AI, in this implementation (Mart, 2017).

3. Methodology

The analysis is guided by the general qualitative interpretative-inductive method described by Thomas (2006), Kahlke (2014), and Harding and Whithead (2016). This method doesn't have a formal methodological framework, but instead emphasizes the inductive reasoning that generates ideas from the collected data. This approach aligns well with the study's aim of exploring the practical applications of AI in language teaching. in various areas of education.

Drawing on personal experimentation with AI models and existing research on AI in education, the study explores several practical activities for integrating ChatGPT – the most widely used AI model – into literature-focused activities in the pre-, during- and post-reading stages in the foreign language classroom. The proposed activities are designed for the instruction of selected classic literary works – works chosen randomly by the authors.

By doing so, the study aims to answer the research questions: *How can AI models be used in pre-reading, during-reading and post-reading activities in the foreign language classroom?* and *What are the benefits of including AI into the literature-based activities in the foreign language classroom?*

4. Results and Discussion

Integrating AI into pedagogical stylistics has the potential to fully transform the way teachers teach literature and language via literature. Recognizing the vast transformative potential of AI – transformative potential supported by research, we propose a framework that outlines how AI can support each stage of a pedagogical-stylistics-focused lesson: pre-reading, during reading, and post-reading activities. Advocates for this "reading stages" approach, such as the British Council (2015), state that this approach is crucial for setting context, and a great way to structure lessons in a way that will help students better comprehend full texts.

4.1. Pre-Reading Activities

ChatGPT, as the focus of this study, can be used in various pre-reading activities that shall take place before the students ever engage with the literary work assigned. Referred to as a way to build anticipation (Crawford et al., 2005), improve engagement (Harmer, 2007), and motivation (Ren & Wang, 2018), the pre-reading stage can help prepare learners for the upcoming reading. This stage aims to activate students' prior knowledge, experiences, and linguistic resources as well as assess their initial understanding of the work and/or author (Crawford et al., 2005). Some typical pre-reading activities include pre-teaching key vocabulary, exploring the topic and cultural context, predicting content based on visuals, brainstorming, addressing and posing questions, etc. (Gardner, 2005; Lazar, 2009; Lightbrown & Spada, 2013; Watkins, 2017).

4.1.1. Using AI to Conduct Background Research

One activity that can be enhanced by AI is the context-exploration activity, proposed by the British Council (2015), in a traditional, non-AI classroom setting. AI tools can

completely transform such an activity, as they can provide summaries of the historical, cultural, and literary contexts of a given work within clicks. And the best part is, they can tailor these summaries to fit different language proficiency levels. For example, when studying a Shakespearean play, ChatGPT can generate concise explanations of the Elizabethan era, theatrical conventions of the time, or relevant biographical details about Shakespeare himself. And it can do so using varying levels of language complexity. For instance, when prompted to provide brief info about the Elizabethan era, suitable for 12-year-old EFL speakers, ChatGPT generates:

"The Elizabethan era (1558-1603) was a time when Queen Elizabeth I ruled England. It's known for a golden age of culture, with famous playwrights like William Shakespeare. People loved the theater, and explorers discovered new lands. Life was different for the rich and poor, and religion played an important role in society."(OpenAI, 2024)

Yet, when asked to do the same, but for C1-level proficiency EFL speakers, the model generates a different output:

"The Elizabethan era (1558-1603), during the reign of Queen Elizabeth I, marked a time of cultural flourishing in England. It saw the rise of great literary figures like William Shakespeare, whose plays became central to English theater. The period also featured significant exploration, expanding England's influence. Religion was a powerful force, and social divisions were evident between the rich and poor." (OpenAI, 2024)

The texts obviously differ in complexity, yet both enable students to build a foundational understanding of a chosen work's broader context, while engaging with the target language in a level appropriate for them.

5.1.2. AI quizzes and games that can help with students' motivation

One of the main goals of the pre-reading activities, as Ren & Wang (2018) state, is to improve students' motivation to read the assigned work. And AI can also be put into good use for this aim. ChatGPT can create interactive and engaging quizzes or trivia games about key themes, characters, or an author's life. For instance, before assigning *Pride and Prejudice* by Jane Austen, a teacher can create a quick AI-generated quiz on Regency-era social customs, fun facts about the era, or literary tropes often found in Austen's works. Such quizzes can potentially spark students' curiosity and set the stage for deeper analysis of the assigned work.

These quizzes and/or games can also be customized to fit students' language proficiency level and age to ensure they are not discouraged by too-complex vocabulary or too-demanding tasks.

5.1.3. Generating Pre-Reading Discussion Prompts

ChatGPT can also suggest thought-provoking questions tailored to the assigned work and students' language proficiency level and interests. Q&A sessions are also part of traditional instruction, but can be re-imagined with some creative prompts by the teacher and AI models such as ChatGPT.

For example, prior to reading Orwell's 1984, ChatGPT could generate questions like:

- *What are the ethical implications of government surveillance?, or*
- *How do you define freedom in a modern society*? (Open AI, 2024)

These prompts can potentially encourage students to draw connections between the text and modern issues that they face daily.

5.2. During-Reading Activities

The during-reading strategies, also referred to as while-reading strategies, help students/readers stay actively engaged with the assigned work, as they read. Some typical activities that center around this idea include annotating (Daniels & Zemelman, 2004), two-column logs (Fisher & Frey, 2014), and formulating questions during reading (McLaughlin, 2015). Though all of these activities have been successfully implemented in traditional literature instruction, at least some, such as the one suggested by McLaughlin (2015), that focuses on posing questions as one reads, can be reimagined with the help of AI.

With the correct prompting, AI can act as an interactive assistant during the reading process, by "asking "students interesting and probing questions, like:

- *What impact does the repetition in this line have on the tone?*
- *How does the choice of imagery in this passage affect its meaning?* (OpenAI, 2024)

To answer the model's questions, students can either enter textual input, or use ChatGPT's voice-command to simulate a "real conversation". In turn, the bot can answer their questions and offer alternative perspectives or corrections.

But the role of ChatGPT can extend into vocabulary-acquisition, too. The model can also help students understand unknown words they encounter while reading. The model can define different words with ease, within seconds, and can help students understand how to use them in different contexts. For instance, when prompted to define and provide usage examples for the word "Hiems" (found in Shakespearean works), the model generates the following output:

"The word "hiems" is a Latin term that means "winter" or "winter season." It is often used in classical literature, particularly in poetry, to represent cold or harsh conditions associated with winter.
Here are five sentences using "hiems":

- *The harsh winds of hiems swept across the village, freezing everything in its path.*
- *In ancient texts, hiems is often described as a time of struggle and survival.*
- *The poet wrote about the beauty of hiems, comparing the snow-covered landscape to a peaceful white blanket.*
- *As hiems approached, the farmers worked quickly to harvest the last of their crops before the freeze.*
- *The legend tells of a god who controls hiems, bringing storms and snow to punish the people for their mistakes.*

In these sentences, hiems refers to the cold, wintry season and is used to evoke the feelings and imagery associated with winter." (OpenAI, 2024)

Such an answer will probably help students understand the word and the way it can be used in different contexts. AI-definitions can, again, be customized to fit students' needs. For instance, when prompted to define the same word but on a 6-year-old-understanding level, ChatGPT provides the following answer:

"Hiems" is a Latin word that means "winter." It's a word used long ago in stories and poems to talk about the cold, snowy time of the year.
Here are five simple sentences with "hiems":

- *Hiems is when the snow falls and the weather gets very cold.*

- *In hiems, we wear warm clothes like coats and hats.*
- *The trees are bare and the ground is covered in snow during hiems.*
- *People like to drink hot chocolate to stay warm in hiems.*
- *Hiems is the time when we can build snowmen and have snowball fights.*

In these sentences, hiems means winter, the cold and snowy season!" (OpenAI, 2024)

The personalization that the model offers is its main asset as its learning output can easily fit the needs of a wide range of students with different abilities, interests, and language proficiency levels.

5.3. Post-Reading Activities

To solidify comprehension, teachers also employ different post-reading activities. Traditionally, they can range from summarizing a text in one's own words (Duke & Pearson, 2009), through creating one's own visuals (Novak & Gowin, 1984), to engaging in discussions with peers or with the teacher (Palincsar & Brown, 1984). There are several ways ChatGPT can be used to re-imagine the post-reading section, to help students expand their linguistic knowledge and literary understanding of the assigned work.

5.3.1. Rewriting Texts and Stylistic Variations

ChatGPT can help students rewrite selected parts of the text, using different stylistic choices. For example, students can:

- Have the model transform formal into colloquial dialogue,
- Have the model rewrite a modern text in a different genre, literary period, or author style,
- Experiment with varying sentence lengths to alter rhythm and tone etc.

Students can then analyze the effects of the changes the model has made. For instance, when prompted to "rewrite" part of Sylvia Plath's Lady Lazarus, into Shakespearean style, ChatGPT's output is as follows:

Lady Lazarus, by Plath	**ChatGPT's output**
I have done it again. One year in every ten I manage it—— A sort of walking miracle, my skin Bright as a Nazi lampshade, My right foot A paperweight, My face a featureless, fine Jew linen. Peel off the napkin O my enemy. Do I terrify?—— The nose, the eye pits, the full set of teeth? The sour breath	I have done it once more, as in each year, One in the ten, I find it comes to me. A walking miracle, with skin so clear, Bright as a lampshade's glow, pale as can be. My foot, a paperweight, it drags, it falls, My face a blank, like linen, fine and white. Peel off the napkin, O my enemy's calls, Do I bring terror, or am I your fright? The nose, the eyes, the teeth, they all shall gleam, The sour breath will vanish in a day. Soon, soon the flesh that once was death's dark dream, Shall find its place within me, come what may. The grave shall feast, yet I shall live anew, This flesh, once lost, shall wear its home in view.

Will vanish in a day. Soon, soon the flesh The grave cave ate will be At home on me	(OpenAI, 2024)

As one can note, the model's output follow's established notions on Shakesperean writings: it produces a sonnet-like output with iambic pentameter and a rhyme scheme of ABAB CDCD EFEF GG. The analysis of the output can potentially help students internalize the effects of stylistic decisions, and help them deepen their appreciation of literary craft.

5.3.2. Post-Reading Discussions

Post-reading discussions with peers and teachers, as suggested by Palincsar & Brown, (1984) can help students understand alternative interpretations. And some of these discussions can also be "facilitated" by AI. This can be done through generating thought-provoking questions that encourage students to reflect on the assigned work and its stylistic elements. For instance, when asked to generate discussion questions about "The Great Gatsby" by F. Scott Fitzgerald, ChatGPT's output includes:

- *How does The Great Gatsby portray the pursuit of the American Dream as ultimately unfulfilling? To what extent do the characters' ambitions and failures reflect this critique?*
- *How does Fitzgerald's use of recurring motifs (such as the green light, the eyes of Doctor T. J. Eckleburg, and the valley of ashes) contribute to the novel's themes and emotional impact?*
- *How does The Great Gatsby challenge the idea of achieving success through hard work and ambition? Do you think these challenges still apply to young people pursuing their dreams in today's world?*
- *Just as Gatsby creates an idealized version of himself to win Daisy, people often curate idealized versions of their lives on social media. How does this phenomenon reflect the themes of illusion and identity in The Great Gatsby? (OpenAI, 2024)*

Such questions may help students connect the form of the text—its language, structure, and tone—with the underlying themes of the text, and connect the text itself with their everyday life. And, of course, the questions can be adjusted to fit students' level of language proficiency and age. Moreover, AI can generate follow-up questions during discussions, guiding students to analyze on a deeper level. These kinds of prompts/questions can help students improve their analytical skills and critical thinking.

Conclusion

Integrating AI into pedagogical stylistics can fundamentally change the way literature and language are taught in today's classrooms. Tools such as ChatGPT offer transformative possibilities, giving educators new ways to enhance and support every phase of reading—before, during, and after the text.

Although this study is limited by its focus on a single model and its qualitative design – both of which produce findings tied to a specific context – we believe it still offers valuable insights. Our results correspond with previous research on AI's transformative potential (Wang et al., 2023; Canosa, 2023; Holmes et al., 2019, etc.) and suggest that ChatGPT can support teachers in rethinking conventional tasks, while providing students with accessible, contextualized information suited to their proficiency level. It can also spark curiosity and motivation through thought-provoking questions, act as a tool for expanding vocabulary, and

encourage students to be creative, explore different stylistic choices, and critically reflect on the generated output.

Future studies could build on these findings by examining how AI might be incorporated into pedagogical stylistics across diverse learning environments and age groups, as well as how other AI models could be implemented in similar classroom practices. While issues surrounding the ethical and responsible use of AI persist, the potential advantages of embedding AI in pedagogical stylistics are substantial. AI is likely to complement existing teaching approaches, though in such a rapidly evolving field, forecasting its future impact remains uncertain.

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TACKLING ORGANIZED CRIME AND THE NEED TO PROMOTE SUSTAINABLE DEVELOPMENT

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ABSTRACT

Introduction: *According to the 2030 Agenda, "To achieve sustainable development, peace and security are necessary; and peace and security will be at risk without sustainable development." The paper will contribute to building Security, peacebuilding and resilience in the context of sustainable development.*
Methods: *When preparing the paper, the author uses general methods, including descriptive, normative, comparative, and content analysis methods.*
Results: *In the final part of the paper, the author concludes that the Global Initiative against Transnational Organized Crime builds a global strategic approach to tackling organized crime by strengthening political commitment to addressing the challenge, building an evidence-based base on organized crime, and developing networks of resilience in affected communities.*
Discussion: *The widening gap between crime authorities and resilience efforts highlights the urgent need to adopt practical strategies to combat organized crime globally. A primary tool for combating organized crime is the ability to develop and manage an effective response strategy.*

Keywords: The Global Organized Crime Index, measurement indicators, Global Initiative Strategy (2024-2026)

INTRODUCTION

Today, the world faces a number of serious and often interconnected threats and challenges, including violent conflict, climate change, growing inequality, the impact of rapid technological innovation, and mass migration. Organized crime is either an enabler of these trends or makes a profit from them. It thrives in the cracks of our broken world. (See: https://globalinitiative.net/analysis/global-initiative-gitoc-strategy-2024-2026/).

For example, criminals transport weapons into and out of conflict zones from Afghanistan to Ukraine and from the Democratic Republic of Congo to Sudan. Criminal groups are increasingly used as a tool to support or overthrow governments, to undermine opponents, or to wage hybrid or proxy warfare. They contribute to the destruction of the natural environment through illegal logging, overfishing, and illegal dumping. They prey on the poor through extortion or by luring victims into human trafficking.

The scientific justification of the paper is – The paper provides an interdisciplinary and critical understanding, analysis of organized crime that is increasingly infiltrating legal economies, and emerging as a powerful economic and social force. The need to promote international cooperation and develop innovative strategies is vital to mitigate this threat (This threat requires a global response). The paper contributes to building security, peace building and resilience in the context of sustainable development or, more specifically, analyzes the relationship between organized crime, corruption and the achievement of sustainable development.

Methods: When preparing the paper, the author uses general methods, including descriptive, normative, comparative, and content analysis methods.

The author uses general methods - Descriptive method - a method that enables a deeper insight and study of the nature of the phenomenon itself, which is the subject of the research; The subject of research is organized crime, developing a strategy to mitigate the consequences of this threat and promoting international cooperation.

The author uses the Descriptive Method – a general method that allows for a deeper insight and study of the nature of the phenomenon itself, which is the subject of the research; (this method contributes to the development of science). The subject of research is organized crime and how to provide an effective response in dealing with organized crime. Dealing with this threat is an important condition for achieving global peace, security and stability.

Normative method - As a basic methodological procedure or technique for collecting data, the author uses content analysis of legal documents - European Union regulations, international documents, reports and internet sources, analysis of strategies, etc.

Comparative method – the author analyzes the global index of organized crime and analyzes the activities undertaken by The Global Initiative against Transnational Organized Crime – proposes new methodologies for analyzing organized crime and designing more effective strategic and political responses to prevent it.

Through the Method of Analysis, the subject of research is broken down into its component parts, its factors, its connections and relationships in a specific space and at a specific time, thus enabling a more substantial understanding of the phenomenon being researched. As a basic methodological procedure or technique for collecting data, the author uses content analysis of domestic and international references, research papers, publications, reports, conference materials, reports and analyses of various articles, journals and content analysis of websites, legal documents - regulations of the European Union, analysis of strategies, international documents, reports and Internet sources.

URGENT NEED FOR RESEARCH AND CREATION OF AN EFFECTIVE RESPONSE TO DEAL WITH ORGANIZED CRIME

Organized crime, in its many different forms, is presented as a threat tp political, economic and social development; it can cause violence and corruption, undermine the rule of law, good governance and democratic processes; can endanger economic growth and poverty reduction and pose significant risks to public health and environmental sustainability (Gerginova, 2021) and (See: Global Initiative against Transnational Organized Crimi programme framework, 2016).

Today, there is an urgent need for research and action on organized crime - promoting new thinking and responses that have a particularly important criminal-political function: setting up a criminal law framework for a proportionate response to increasingly serious and organized forms of crime by increasing the efficiency of prevention, detection and prosecution measures – This facilitates the work of the institutions responsible for implementing the laws, providing clearer direction and tends to increase their efficiency in their work and contributes to reducing the loss of human and financial resources.

Organized crime is a growing threat to security, development, governance and the environment. It is considered an increasingly serious threat to the rule of law, democracy, the rule of law, international peace and stability. In order to solve this security problem, it is necessary to act from the perspective of national security and the protection of national interests, as well as from the perspective of achieving the protection of the interests and values of human and international security (Piccarelli, 2008 : 462).

Despite the global nature of this threat, there is no strategy to prevent and address it. This hinders the ability of states to deal with this serious problem, - it undermines noble goals such as achieving the Sustainable Development Goals, slowing climate change, as well as resolving conflicts and building peace. Therefore, GI-TOC is leading a process to formulate the building blocks of a global strategy against organized crime. (See: https://globalinitiative.net/initiatives/strategy/).

Through "organized corruption," state-embedded criminal actors use all possible means to cling to power and exercise patronage at the expense of public resources and institutions. Furthermore, criminal actors are quickly adapting to the latest technology, using ransomware and artificial intelligence, or moving money or sending messages using encryption.

By 2040, significant progress and reach of organized crime is expected, through the exploitation of climate crises, geopolitical conflicts and technological advances.
Some authors (such as Phil Williams) point to a so-called "fifth wave" of organized crime – organized capital will capitalize on markets of scarcity, taking advantage of disruptions in basic resources such as water, minerals and energy caused by climate change.
Criminal networks can infiltrate legitimate markets, blur the lines between legal and illicit activities, and use scarcity as a driving force for growth (See: The Global Initiative Against Transnational Organized Crime WMO Building, 2nd Floor 7bis, Avenue de la Paix CH-1211 Geneva 1 Switzerland).

Using new tools such as artificial intelligence, autonomous vehicles and 5G technology, criminal organizations have reached new levels of sophistication. This makes it more difficult for law enforcement agencies to counter their reach and resilience. Meanwhile, geopolitical tensions are exacerbating the situation, as some authoritarian regimes use criminal networks as an extension of state power, offering criminal organizations safe havens and strategic support in exchange for destabilizing activities abroad.

The "Fifth Wave" raises urgent questions about global preparedness to combat the possible evolution of organized crime and challenges policymakers, law enforcement agencies, and international organizations to rethink their approach to organized crime in a rapidly changing world. Stresses the importance of proactive strategies that go beyond traditional crime-fighting tactics. The Fifth Wave advocates for comprehensive international cooperation, adaptive policymaking, and innovative technology to address this deep-rooted threat.

THE GLOBAL ORGANIZED CRIME INDEX 2023

The next content that I analyze in the paper is aboutThe Global Organized Crime Index 2023. This index, reveals the reach and complexity of transnational organized crime (assesses the capacities of 193 UN member states to counter criminal threats). Along with the original 10 indicators of the criminal market, the Organized Crime Index 2023 introduced five new indicators for measuring criminal activity: financial crime, cyber-related crimes,illicit trade in excise goods, counterfeit goods and extortion and racketeering.
(See: https://globalinitiative.net/analysis/ocindex-2023/ and See:
https://globalinitiative.net/analysis/conflict-fragility-resilience-organized-crime-index/).

The Global Index also includes private sector actors as a new type of "criminal actor." The Global Index provides a broader perspective on emerging threats and emphasizes a commitment to providing critical data that can help support the identification of effective response strategies. By using data-driven tools, the Index now offers more comprehensive and refined analysis and improves collective understanding of the illicit economy and capacities for building resilience. With the publication of the Global Organized Crime Index in 2023, the aim is to encourage global actors (from policymakers to civil society) to adopt effective, evidence-based strategies in the fight against organized crime. The latest edition of the Global Organized Crime Index (2023) reveals that greater attention must be paid to tackling financial crime – now ranked as the world's largest criminal market. Furthermore, it is vital to identify and disrupt the role of professional facilitators in the private and public sectors who operate at the border between illegal and legal markets.

THE GLOBAL INTIATIVE AGAINST TRANSNATIONAL ORGANIZED CRIME

The next content I analyze is about The Global Initiative against Transnational Organized Crime - this initiative was established in 2013. Its vision is to mobilize a global strategic approach to tackling organized crime by strengthening political commitment to addressing the challenge, building an analytical evidence base on organized crime, disrupting criminal economies, and developing networks of resilience in affected communities (See: https://globalinitiative.net/about-us/network/).

Today, GI-TOC is the only civil society organization dedicated to analyzing and responding to illegal economies. It began as a small network, mostly composed of members of the police force, concerned about the harm caused by illegal economies(See: https://globalinitiative.net/wp-content/uploads/2024/02/The-2024%E2%80%932026-strategy-GI-TOC-February-2024.v4.pdf).

GI-TOC has a Resilience Fund that supports more than 170 organizations and individuals, in 55 countries; Creates an annual output of more than 90 high-quality and influential publications that shed light on a wide range of criminal markets and actors from different parts of the world; GI-TOC has published the first Global Organized Crime Index, covering all 193 UN member states, with the additional feature of measuring each country's resilience to organized crime; GI-TOC is a leader in proposing new methodologies for analyzing organized crime and designing more effective strategic and policy responses to prevent and combat it; GI-TOC has developed more direct measures to protect communities and reduce organized crime, by strengthening community resilience and disrupting criminal markets.

The mission of GI-TOC is to provide relevant and timely analysis and adoption of recommendations based on best practices, real-world experience, and innovation. Solutions are proposed at local, national, regional, and global levels among policymakers and change makers.

GI-TOC has identified four focus areas: 1. Better analysis and evidence 2. Market disruption 3. Building resilience 4. Inclusive networks of action.

Advancing the work of GI-TOC in all four areas, collaborating with partners and relevant institutions, and building networks for action, represents the best strategy for combating organized crime and reducing its impact. The primary goal set out in the strategy is to reduce organised crime and mitigate its negative impact on people, the environment, business and states. Any positive change needs to be based on solid current information and evidence that provides an understanding of the local political economy embedded in the global geopolitical context.

The GI-TOC Network constitutes the Annual General Meeting of the Global Initiative and serves as a forum for influence, collaboration, coordination and expertise. It is a common

space where honest debate can take place, experiences can be shared, connections can be developed across institutional lines and support can be sought from all those affected by the impact of organized crime. Membership in the Network ensures strengthened global responses to the challenges of organized crime.

The Resilience Fund complements the ongoing work of the Global Initiative to Incubate Resilience in Communities Damaged or Threatened by Criminal Governance. The Resilience Fund identifies and empowers key civil society actors and builds their operational capacity to create resilience networks in communities affected by organized crime and violence (See: https://globalinitiative.net/initiatives/resiliencefund/).

Recognizing the importance of resilience at the local level, the GI-TOC Resilience Fund launched the fifth edition of its Resilience Fellowship (this fellowship provides a platform for cross-sectoral, global, and interdisciplinary collaboration between civil society actors, human rights activists, journalists, artists, scholars, policymakers, grass-roots community leaders, and others working to counter the effects of organized crime.

GLOBAL INITIATIVE STRATEGY FOR COMBATING ORGANIZED CRIME, PLANNED FOR THE PERIOD 2024 - 2026

The 2024-2026 strategy maps out the goals that GI-TOC intends to pursue (this organization aims to improve the knowledge and evidence base on illicit economies and strengthen resilience and multilateral responses).

The objectives of the strategy are to: (See: https://globalinitiative.net/initiatives/strategy/)

- Increase understanding, analysis and anticipation of organized crime;
- Encourage "global" approaches to preventing and countering organized crime; namely local and global efforts that are more networked, inclusive and effective;
- Energize the global debate around transnational organized crime and mobilize action to reduce the harmful impact on people, the environment, businesses and states;
- Collect and share good practices in order to have a toolbox of actionable responses relevant for different stakeholders around the world, who are dealing with a wide range of criminal markets;
- Enhance cross-border law enforcement cooperation based on new thinking, innovation, and coordination of responses to TOC;
- Empower local initiatives to affect positive change and build more crime-resilient communities.

The objectives set out in the strategy are aimed at addressing some of the vulnerabilities highlighted by the 2023 Global Organized Crime Index and building on the recommendations made by the GI-TOC on possible elements of a global strategy against transnational organized crime.

STRATEGIC GOALS FOR 2024–2026

In the paper, I also analyze content related to strategic goals in order to achieve better analysis and address certain vulnerabilities; identify possible market disruptions; identify inclusive networks of action – all of this is ultimately related to building community resilience to organized crime as a contemporary threat.

First strategic goal is Improving analysis and evidence base - Policies on illegal economies will be researched – this will contribute to developing better analysis and enriching the evidence base to guide informed responses and set priorities.

Over the next three years, GI-TOC will continue to publish high-quality reports on illegal economies. This will be done by expanding its geographical and thematic focus.

GI-TOC will focus its work on topics, regions and countries where illicit economies have a growing impact. This includes financial crime, environmental crime, extractives, state-embedded actors, urban organized crime, arms trafficking, facilitators along supply chains, and the relationship between violent conflict and illicit economies. To ensure truly global coverage, GI-TOC will increase its presence in Asia and Latin America (including in the Amazon) and increase its focus on Western Europe, Central Asia and Afghanistan.

In 2025, GI-TOC released the third edition of the Global Organized Crime Index. This flagship publication will allow GI-TOC to refine its methodology and measure progress against the results of the first two editions (2021 and 2023). Furthermore, over the strategic period, the Index team will seek to use the data from the Global Index in creative ways to identify emerging trends and the connection between illicit economies and global megatrends. GI-TOC will strive to make a meaningful contribution to the 15th UN Crime Congress, scheduled for 2026.

The second strategic goal is - DEVELOP INNOVATIVE PROGRAMMING FOR MARKET DISRUPTION OVERALL OBJECTIVE:

Develop programming for disruption and reduction of criminal markets. Although organized crime is a global menace, there is no global strategy to counteract it. That is why the GI-TOC will publish a report mapping out ideas of a global strategy against organized crime, which includes actions for governments, law enforcement agencies, the private sector and civil society to more effectively prevent and counteract organized crime.

MAIN GOAL - The growing availability of information in the public domain allows for the democratization of information collection and analysis on illegal economies, while technology can be used as a tool for good, not just as an enabler for criminal actors.

During the strategy implementation period, GI-TOC will continue to use open source intelligence (OSINT) and satellite data to enhance intelligence gathering. It will also use technological tools to identify and attempt to disrupt online markets.

The third strategic objective is- STRENGTHENING RESILIENCE IN VULNERABLE COMMUNITIES

GENERAL GOAL: - To reduce the harmful impact of organized crime by highlighting the plight of victims and survivors, and by supporting - and, where necessary, initiating - community-based initiatives that strengthen resilience to organized crime.

GI-TOC is a civil society network designed to help members of civil society confront and build resilience to organized crime.

To this end, one of the most important pillars of GI-TOC is the Resilience Fund, which has supported over 170 individuals and civil society organizations in 55 countries around the world.

Between 2024 and 2026, GI-TOC will seek to expand the Resilience Fund – both in terms of its resources and its geographical reach. A particular focus will be placed on countries that score low on the Global Resilience Index. Furthermore, innovative pilot projects will be launched to promote community resilience and disruption in hotspots identified in GI-TOC research, for example in West Africa. GI-TOC will maintain a strong focus on human rights in relation to organised crime.

The fourth strategic objective is EXPANDING ACTION NETWORKS

MAIN OBJECTIVE: - Building coordinated, multi-stakeholder and inclusive networks of action and integrity, with global impact and reach.

Generating debates around proposals for a global strategy against organized crime will enable the GI-TOC to strengthen its networks of action. For example, a triangular relationship could be strengthened between the GI-TOC, UNODC and INTERPOL to spearhead the strategy formulation process, capitalizing on the possibility of putting organized crime on the agenda of the Future Summit, scheduled to take place in 2024, and events leading up to and marking

the 25th anniversary of the United Nations Convention against Transnational Organized Crime in 2025 and the 15th UN Crime Congress in 2026.

The fifth strategic objective is IMPROVING OPERATIONAL EFFICIENCY
MAIN OBJECTIVE: - Strengthening the operational efficiency of the organization to ensure good governance, effective oversight and accountability, sustainable growth, safe and motivated staff, and professional, high-profile results.

DISCUSSION

The widening gap between crime authorities and resilience efforts highlights the urgent need to adopt practical strategies to combat organized crime globally. A primary tool for combating organized crime is the ability to manage and develop an strategy for providing an effective response.

Regarding the implementation of future research, I propose the topic related to the concept of strategy and what principles a strategy for dealing with a particular threat should be based on - in my paper - dealing with organized crime.

-As subtopics for future research, I propose - research into the factors that enable organized crime to gain support in society.

-Organized crime markets need to be mapped, specifically, the various sectors, goods, services, enablers and infrastructure, which together constitute criminal economies.

-to conduct an analysis of organized crime groups - along with their structure, activities, cooperative and competitive relationships with other organized crime groups located within the country, and outside the country (the latter requires the development of international cooperation). Certain approaches help to better understand the connections between various organizations and key enablers.

Strategies are useful tools, as they offer a mechanism through which multiple actors from across society can come together (these actors are of varying capabilities in pursuit of common visions and goals) (See: Handbook on strategy against organized crime, 2021).
They also represent a strong signal of political intent at the national and international levels, justifying greater action and mobilization of efforts and resources.

By bringing together different sectors and nations, national and regional strategies can effectively help build international resilience networks that offer protection from the problem at both local and global levels. Strategies also form the basis for a more effective response and can be used with a variety of tools, tactics and techniques to achieve defined objectives.
The study of organized crime, and more specifically, what constitutes an effective response to the phenomenon, remains a subject of ongoing research and debate. Similarly, existing strategies vary considerably in emphasis, detail, and scope, a product of differing political priorities, legal frameworks, resources, and cultural norms.

A strategic analysis of organized crime should encompass at least three dimensions:

First, it should understand the structural drivers of organized crime – factors that enable organized crime to gain support in society and to become entrenched in various structures of society. These include instability, economic inequality, political or social exclusion, lack of access to key services, (endemic) corruption, etc. Such an approach can help identify the sources of legitimacy of organized crime, as well as the role of criminal actors and interests in underpinning the existing political system.

Second, the results of the analysis should map organized crime markets, specifically the various sectors, goods, services, enablers, and infrastructure that together constitute criminal economies. Examples of sectors could include: the financial sector, which includes various mechanisms for transferring funds; the real estate sector, which provides a conduit for acquiring property as well as for money laundering; and transport services, which are crucial

for the movement of illicit goods. Geographical hotspots, such as border areas, urban centres and transhipment points, should also ideally be identified at this stage.

Third, the analysis should encompass organized crime groups, along with their structure, activities, collaborative and competitive relationships with other organized crime groups located both within and outside the country (the latter requires the development of international cooperation). Certain approaches, such as mapping organizations on social networks, help to better understand the connections between various organizations and key enablers.

Together, these different components lead to a more nuanced understanding of the political economy of organized crime, as well as an understanding of the different risks and trade-offs associated with the various interventions and policies contained in the strategies.

An effective strategy, above all, needs to be clear about its overall goal – to define the desired change in relation to organized crime and work backwards from there – an approach sometimes called a "theory of success." While each country and region is unique, analysis of strategies and responses to organized crime around the world suggests four overarching principles that are broad enough to apply in most contexts.

They are useful because they act as broad pillars and conceptual starting points against which different goals and opportunities can be located.

These principles are as follows:

PREVENTING organized crime from (re)infiltrating communities, economies and political institutions. The aim of this principle is to build resilience to organized crime, denying it the opportunity to penetrate society.

PROSECUTION of organized crime groups and their illicit profits, as their activities increase business costs and risks. This principle should reduce and disrupt the economy of organized crime.

PROTECTION of vulnerable persons and victims from (further) harm. This principle highlights the harm and injuries that organized crime inflicts on people with a victim-centered approach that incorporates human rights and gender perspectives.

PROMOTING partnerships and cooperation at all levels, including across international borders – a whole-of-society approach. This principle, which lies at the core of the Organized Crime Convention, emphasizes the importance of partnerships at local, national and international levels, operating across governmental, non-governmental and private sectors.

Although these principles are relatively universal, their application and the balance of efforts and resources between them will need to be adapted depending on the characteristics of the problem in the country or region.

Strategies to combat organised crime also set specific objectives - rigorously defined specific objectives and clear deliverables are key to ensuring that they lead to the type of systemic change needed to address the phenomenon of organised crime. It follows that the specific objectives should work together as an integrated and systematic response by addressing the various weaknesses identified in the analysis phase, which constitute the various components and enablers of the organised crime system.

CONCLUSION

In the final part of the paper, the author concludes – Organized crime manifests itself differently in different contexts, including conflict settings. The resilience indicators in the Global Organized Crime Index 2023 are multi-sectoral, targeting areas of society at risk of exploitation by criminal groups through political, economic, legal and social measures. There is a continuing and urgent need for research and action on organized crime to promote new thinking and responses to understanding criminal markets, actors and ecosystems.

The Global Initiative against Transnational Organized Crime builds a global strategic approach to tackling organized crime by strengthening political commitment to addressing

the challenge, building an analytical evidence base on organized crime, disrupting criminal economies, and developing networks of resilience in affected communities.It will contribute to promoting sustainable development, improving the management of global commons, reducing the impact of environmental degradation, and strengthening multilateral cooperation.

The strategy for combating organized crime planned for the period 2024 – 2026 is designed to provide direction for GI-TOC for the next three years. It should also enable GI-TOC to help the world develop a clearer direction for mitigating the worst effects of the growing problem.

By summarizing the contents of the paper, and taking into account the strategic goals and key activities outlined in the strategy for tackling organized crime (planned for the period 2024 – 2026), we can determine the main measures of success (which are expected to be implemented by the end of 2026:

Recognition of the GI-TOC as the leading global civil society partner in combating organized crime; Close strategic partnerships between the GI-TOC and key actors, including UNODC and INTERPOL, as well as regional organization; Adoption of a global strategy against organized crime; Use of the Global Index as the basis for measuring improvements in combating organized crime; A Resilience Fund with annual capital of at least €2 million; Enhanced in-house expertise on financial crime and the impact of Enhanced in-house expertise on financial crime and the impact of technology on illicit economies; A network of GI-TOC observatories with truly global coverage; Recognition of the GI-TOC's work on the use of technology to disrupt criminal markets, particularly through the ECO-SOLVE project; A foresight group recognized for innovative strategic anticipation.

It is necessary to Develop an online tool to collect and share good practices in preventing and combating organized crime; Promote policies that address the threat posed by state-embedded actors; and encourage more common approaches to reduce the links between organized crime and corruption.

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ARCHAEOLOGICAL HERITAGE, CULTURAL DIPLOMACY AND THE SUSTAINABLE DEVELOPMENT OF INTERNATIONAL RELATIONS

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ABSTRACT

Introduction: *This paper addresses the critical reevaluation of cultural diplomacy's role in 21st-century international relations. In an era where the effectiveness of soft power tools is often questioned, this study aims to explore a novel methodological approach by examining the intersection of archaeological heritage and cultural diplomacy to foster sustainable development in global affairs.*
Methods: *The research employs a qualitative analysis of existing literature and specific case studies in the field of heritage diplomacy. It examines the mechanisms through which archaeological sites, artefacts, and cultural narratives are integrated into diplomatic strategies to promote intercultural dialogue and sustainable practices.*
Results: *The analysis demonstrates that archaeological heritage, due to its profound impact on identity formation and cultural narratives, functions as a crucial component of the "software" of modern societies. The findings indicate its significant potential as a soft power tool to enhance international relations by contributing to peacebuilding, preserving cultural diversity, stimulating responsible tourism, and supporting economic growth through heritage preservation.*
Discussion: *The study concludes that integrating archaeological heritage with cultural diplomacy strategies offers a powerful means to advance Sustainable Development Goals (SDGs) while strengthening political and economic ties. The results underscore the broader applicability of heritage diplomacy in global peace and cooperation efforts. The paper also discusses the inherent challenges of leveraging complex cultural elements and suggests areas for further research into the practical implementation of these interdisciplinary strategies.*

Keywords: Cultural Diplomacy, Archaeological Heritage, Interdisciplinarity, Sustainable Development, International Relations

INTRODUCTION

Culture and identities, and through them, or in mutual relations with them, archaeology and archaeological heritage, have played and continue to play an important role in international relations. Some might say that this role has decreased in the time of global instability and hard power in international relations. Others might analyze that these cultural phenomena are rooted in most, if not all global, regional and local conflicts.

These diverse views on culture and archaeology in international relations are not a result of opposing data emerging from field analyses, geographic or cultural differences, but rather related to the nature of modern scientific research. In the context of high specialization of different research fields, a process that accelerated in the twentieth century, the narrow focuses of different scientific fields, produce this mirage of discrepancies.

Thus, in the acceleration of the globalization process, some theorists of international relations see trends of pragmatism and dismissal of complex cultural and traditional elements of protocol and diplomatic practice. On the other hand, the anthropologists, sociologists and researchers of other social disciplines might see this acceleration process in totally different dimensions. Thus, the emerging cultural misunderstandings and conflicts, are deeply rooted in culture and identity, which were tremendously influenced by the theories and the artefacts of archaeology in the last two centuries, if not even before. In addition, archaeology and archaeological heritage, as part of the wider focus on the wisdom and knowledge coming from the past, also had great influence on the development of other social sciences, as well as on the development and premises of international thought.

However, contemporary scientific approaches leave little room for axiomatic assumptions, and careful analysis of this area is even more important, given that international relations constitute the primary field in which the development, influence, and reciprocal influence of archaeology and archaeological heritage are defined and tracked in this paper.

The study of these relations gains additional scientific weight when considering that theories of international relations are not only retrospective views on world affairs. Instead, they are deeply socially and politically conscious or engaged analyses aimed at offering answers and solutions to current problems, as well as visions and paths toward transforming the present or future. According to Professor Thomas Smith, theorists of international relations, as well as those from some other social sciences and disciplines, while "trying to explain events and their root causes, often already (with one eye) see toward the future." This pre-deterministic nature makes the protagonists of this scientific discipline active and prominent elements who, consciously or subconsciously, directly or indirectly, open new paths and transform the "international system" with their visions and ideological solutions. In this context, the possible influence and treatment of culture, identities, archaeology, and archaeological heritage by theorists of international relations in the modern world anticipate their transcendent importance and, more significantly, transform these phenomena into an even more important agent through which theorists directly influence and shape global relations.

METHODOLOGY

The research methodology for this study is interdisciplinary, combining approaches from archaeology and international relations (IR) to explore the complex interactions between culture, identity, heritage, and global politics. The methodology is designed to bridge the gap between the material and cultural evidence and theory of archaeology and the theoretical frameworks of IR, particularly in relation to ontological security and glocalization.

First, the research employs a qualitative approach that critically analyzes archaeological artifacts, heritage narratives, and their socio-political significance within contemporary international relations. This involves the application of interpretative strategies inspired by Foucauldian archaeology of knowledge, which seeks to reveal how objects,

concepts, and identities are constructed and maintained through power relations and discursive formations. A key aspect is examining how archaeological heritage contributes to states' identity narratives and ontological security needs.

Second, the methodology integrates theoretical analysis from IR, drawing on ontological security theory and constructivist paradigms to understand state behavior beyond material security. It considers states as actors seeking stable self-identity through cultural resources, including archaeology and heritage, which become pivotal in both national security and diplomatic contexts.

Third, the research includes a review of existing literature from both fields. Attention is given to how globalization and glocalization processes impact cultural diplomacy, identity reinvention, and intercultural dialogue.

Finally, the approach endorses collaboration between archaeologists, political scientists, sociologists, and anthropologists to ensure comprehensive analysis, reflecting the multifaceted nature of the research topic and allowing for robust interdisciplinary insights.
This methodology ensures a nuanced understanding of how archaeology and archaeological heritage function as dynamic agents within international relations, helping to explain contemporary global challenges and identity conflicts through an integrated analytical framework.

Global Challenges and New Interdisciplinary Solutions

The ever-intensifying economic, cultural, and technological globalization is not just creating a united universe. It has also managed to unite people across the globe in creating multiple new universes. A technological multiverse emerges from the cooperation, knowledge, creativity, and innovation of the whole of humankind. And yet, there are numerous individuals, communities, and societies around the world that are raising the question: Are we the winners or losers of this perpetual, complex, and irreversible process? We are far away today from the idealistic vision of the „end of history "proposed by the prominent global thinker Francis Fukuyama at the end of the last millennium. It is true that the globalization process has transformed dramatically life, culture, societies, and even values in numerous developing countries and the most isolated communities.

However, it also changed and challenged the society, culture and the value systems of individuals, communities, and societies that perceive themselves as leaders and even main protagonists of the globalization process. It seems that today, many in the East and West are united, under the famous words of Edward Said.

This famous theorist of the east-west relations underlined an important conclusion many decades ago that: "No one finds it easy to live uncomplainingly and fearlessly with the thesis that human reality is constantly being made and unmade and that anything like a stable essence is constantly under threat" (Dıaz-Andreu 2007, pp.11).

This emerging global fear among individuals, communities, and societies threatened by the global rapid and omnipresent change is urging us to think of new, innovative, and more adequate paradigms of global relations (Kinnvall 2004).

It is not enough today to rest on the comparisons of the unique knowledge of the past of archaeologists, historians or philologists. Instead, one must consider combining the approaches, methods and paradigms of different social and other sciences. On this occasion, and in order to objectivize the relation of archaeology with contemporary international relations, we will include in the equation the additional paradigms of contemporary international relations emerging from other disciplines.

The first is recently labeled as ontological security. While many regions of the world today are confronted with physical insecurity, including terrorism, organized crime, and war, the ontological insecurity is a global omnipresent threat. A looming threat that strongly affects even the most prosperous and stable societies and communities.

Multiple groups, communities, societies, and countries, irrespective of their circumstances in the global processes, feel less and less secure in their visions for themselves and the world. They are left with an endemic feeling that the global change aims towards undermining of their identity, culture, morals, and way of life. This ontological insecurity, well known from the earlier psychological theory, creates extremely anxious, isolated, and irresponsible people. However, we are increasingly understanding that the same powerful dynamics also create anxious, self-isolating, and irrational groups, elites, and countries. Therefore, bearing in mind the inevitability and the news effects of the global change, we are obligated to invest heavily in culture and intercultural dialogue. We should not just permit and look more favorably, but also support the processes, policies, and local, national, and regional institutions aiming to reimagining and reinventing once own values and traditions in the ever-changing world. We are wrong to judge them collectively and prematurely as purely localist and disruptive to global cooperation and security. Instead, this global burst and contemporary searches for identity should be seen as an integral part of the globalization processes. It is the contemporary research in archaeology and ancient globalization that are teaching us that even the most radical localisms represent an integral part of the globalization processes (Tevdovski 2024).

Ontological (in)security and Archaeology

Ontological security represents a concept thatentered International Relations (IR) from psychology, but also from the fields of sociology and social theory. The concept and the growing literature on Ontological Security Theory (OST) is still deeply rooted in the paradigms developed in these fields (Giddens, 1984 and 1994), but increasingly relates to paradigms, different aspects and schools of International Relations (Huysmans 1998, Kinnvall 2004, Mitzen 2006, Steele 2005, 2008, Solomon 2018).

Its main premises explain that states seek not only physical safety but also a stable and continuous sense of identity over time. While the pursuit of ontological security is a relatively novel, or at least significantly refurbished, concept, its relevance and practical applications are accelerating rapidly.The need for a reliable and coherent self-narrative that enables a state to maintain agency and coherence in a complex and often uncertain international environment seems to gain new momentum in the last decades.

In addition, aspects of this theory might serve, or be interpreted with a political science term, as "cross-cutting cleavages", that provide new bridges in the traditional divides of IR theory. Thus, traditionally the realists in IR were dominantly related to the themes of national interest and physical security, and the idealists were left with the softer elements and proposals of policies and shared or global (sometimes cosmopolitan) interest (Jackson 2005, pp. x, 3-4). In this context, the Ontological Security Theory (OST), creates a new bridge between the national interest and the soft, and even typically constructivist elements, such as culture and identity. While, traditionally, security analyses were focused primarily on physical survival and protection against external threats, ontological security highlights and redefines the psychological and identity dimensions of state behavior into an important and independent research area.

Some researchers, like Jennifer Mitzen (2006),tend to expand the concept by linking ontological security-seeking to the state's engagement in routinized relations with significant others. They argue that states achieve ontological security, much like the individuals, by stabilizing their identities through predictable routines and social interactions with others (Giddens, 1984 and 1994). Importantly, Mitzen argues that states may be attached to certain conflictual or dilemmatic relationships because,as such,they provide a consistent sense of self, even at the risk of physical insecurity. It is in this context that the importance of archaeological artifacts and narratives, that have transformed in the last centuries into the "holy grails" or "relics" and "holy books" or "national oaths" of nations is becoming

immense. The deeply rooted sense of belonging, related to these national *sacrums*, elevated them in different contexts to the level of highest national interest, and was traditionally related to the theoretical analyses of the irrational in the policies of the states. However, this paradigmchange, challengessuch classical realist perspectives by revealing that enduring conflicts may persist not only due to physical security concerns but also because they satisfy states' deeper identity needs (Steele 2008). At the same time, it obliges states, and theorists as well, to refocus on institutions, policies and strategies that prioritize and prepare these "national cultural resources". Despite the ideological gaps concerning their utilization: being it for the sake of national self-interest or dialogue with others, for ideological and cultural dominance or building bridges in the past and the future. It becomes quite obvious that archaeology and the disciplines protecting, promoting and even "inventing" and "reinventing" heritage and identity are becoming universally acclaimed as important elements in national security and international policies.

Thus, Steele (2005, 2008) develops a comprehensive framework for ontological security in IR, that is of great interest for its potential relations with archaeology. He suggests that ontological security for states involves possessing coherent answers to fundamental existential questions that reflect the state's self-identity. More importantly the arguments of this authorgo a step further. Stressing the importance of internal debates and reflexivity within states about their identity and security, he convincinglyimplies that there is a need for investment in research and related institutions. Such infrastructure would be the guarantee for the capability of the state to absorb this constant internal societal dialogue and to transform it into a coherent and productive set of answers to the constant and ever-evolving identity insecurities of its entities.

This aspect of Ontological Security Theory (OST) is moving beyond the idea that states simply react to external threats. It frames security seeking as also about maintaining a consistent narrative and routine that affirms the state's self-understanding over time. The work of Steele also highlights the role of emotions and identity reflexivity (Steele 2008), which implicitly includes the new concepts of "living heritage" and the interpretative dimensions in archaeology, both on scientific and educational level, as integral and useful elementsfor state behavior and security practices.

In summary, ontological security twist in IR, bring not just prosperity, happiness and social cohesion, butalso security of societies and their relations, directly into the sphere of culture, identity and belonging. Thus, it becomes closely related to the capabilities, professional history and impact of archaeology and archaeological heritage in society. This perspective might explain why different states are reengaged in important efforts to promote and protect their identity. What used to be explained as irrational behavior in traditional IR analyses, might be considered in present asstrategic efforts for avoiding ontological insecurity. This new relation with archaeology might also open analytical space to understand how intertwined security is with identity, emotional attachment, and the quest for meaning in global politics.

Glocalisation as the smiling face of the globalization process

While ontological security and insecurity locate some of the key problems of contemporary international relations, another paradigm not just evaluates challenges but proposes solutions. The idea of "glocalization" arrived in international relations theory from the business sector. It originates in the Japaneese "dochakuka", that can be loosely translated as "global localization" (Pitts & Versluys 2014).

The Japanese entrepreneurs inventing this paradigm explain that global goods, materials, technologies, and, most importantly, ideas have to be additionally locally flavored in order to be well received by local audiences (Robertson 1995). In our case, we should bear in mind that the numerous emerging globalizing tendencies will not bring only complexity,

but will also lead towards increased dialogue, ownership over global processes, and ultimately increased social cohesion. This approach that supports multiple reinventions and reinvigorations of local and regional values, customs and worldviews is a long, costly and many times frustrating process. But its inclusiveness is the only guarantee for a more secure world of individuals and communities with self-esteem and vigor for global competition and interaction.

CONCLUSION

The interdisciplinary relationship between archaeology and international relations offers valuable insights into the ways in which culture, identity, and heritage shape global politics. Archaeological theories contribute to understanding not only the material and historical contexts of societies but also the symbolic and narrative dimensions that influence state identities and their behavior in the international system. These contributions challenge traditional IR paradigms by emphasizing the importance of cultural continuity, emotional attachment, and identity security in global affairs.

Archaeology enriches international relations by providing frameworks to analyze power structures, economic systems, and cultural diplomacy over long temporal scales. It also highlights the political significance of heritage and artifacts in contemporary identity conflicts and diplomatic negotiations. Moreover, recent approaches in IR that incorporate ontological security demonstrate how heritage and cultural narratives become crucial in sustaining state coherence and agency amidst global change.

This evolving dialogue between archaeology and IR fosters new methodologies that bridge material evidence with social theory, offering holistic models to address current global challenges such as identity conflicts, globalization, and intercultural dialogue. Ultimately, integrating archaeological perspectives with IR theory enhances our capability to comprehend the past's impact on present and future international relations, advocating for more culturally informed and inclusive policies.

Thus, the study of archaeology in the context of international relations transcends mere historical inquiry. Instead, it becomes a critical tool for understanding complex political realities and developing pathways toward peaceful global coexistence and cooperation.

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CORRELATION BETWEEN FUNCTIONAL ABILITY AND FALL RISK AMONGINSTITUTIONALIZED ELDERLY RESIDENTS

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ABSTRACT

This research examined the relationship between functional ability and fall risk among institutionalized elderly persons. The objective was to determine how levels of independence in activities of daily living measured by the Barthel Index correlate with general functional capacity and vulnerability to falls. A quantitative, cross-sectional design was used including 30 participants from 53 to 89 years from a residential care home in Kravari, North Macedonia. Functional performance was assessed across ten activities of daily life categories, and descriptive and inferential statistics were performed using Pearson correlation, t-test, analysis of variance, and multiple linear regression. Results indicated that 40% of participants had severe dependence, while 26.7% were totally dependent, with a mean Barthel score of 47.83 ± 32.92. Strong positive correlations were found between total functional independence and subdomains of mobility ($r = 0.927$), transfer ($r = 0.897$), and toileting ($r = 0.861$), all with $p < 0.001$. The regression model found toileting, feeding, and dressing as predictors of independence ($R^2 = 0.891$, $p < 0.001$). These results confirmed that reduced functional ability is associated with increased fall risk and stress the importance of rehabilitation focusing on mobility, postural control, and self-care restoration in institutionalized elderly persons.

Keywords: functional ability; fall risk; Barthel Index; geriatrics; rehabilitation; mobility; independence

INTRODUCTION

Falls represent are of the main causes of morbidity, mortality, and loss of functional capacity among elderly persons, especially those living in institutionalized environments such as nursing homes and palliative care facilities (Vaishya & Vaish, 2020; Neah Albasha et al., 2023). With older age, the interaction between physiological, cognitive, and environmental factors increases vulnerability to falls that result in serious health consequences and reduced quality of life (Trevisan et al., 2021;Nazarko, 2022; Liu et al., 2025). According to the World Health Organization, approximately 28-35% of people of 65 years and more experience at least one falls each year, and this proportion rises to 32-42% for persons over 70 years (WHO, 2008). The prevalence is higher in institutionalized elderly home cares where fragility, multimorbidity, and limitations in mobility are common (Zhang et al., 2024).
Functional ability, the capacity to perform activities of daily living independently is a key factor in maintaining autonomy and preventing falls among the elderly (Tornero-Quiñones et al., 2020). Declines in muscle strength, balance, coordination, and sensory function impair postural control that increases fall sensitivity (Wang et al., 2022). Assessing functional ability with standardized instruments offers a deeper comprehension into the physical capacity of the elderly persons and can serve as an early indicator of fall risk (Bassett et al., 2020; Arsovski et al., 2025). Conversely, recurrent falls can cause further functional decline, creating a self-perpetuating cycle of dependency, inactivity, and fear of falling (Chandrasekaran et al., 2021).

Institutionalized elderly residents are vulnerable group due to factors such as advanced age, chronic diseases, medication use, and limited physical activity (dos Reis & de Jesus, 2015). Environmental hazards, insufficient staff-to-patient proportions and inadequate rehabilitation programs also worsen fall risks (Clemson et al., 2019). Accordingly, finding the relationship between functional ability and fall risk is important for developing preventive interventions and rehabilitation strategies that promote safety, independence, and well-being (Hamm et al., 2016).

Previous research demonstrated associations between lower functional performance and increased fall incidence within this population (Smee et al., 2012; Ho et al., 2021; Sun et al., 2024). However, the extent and strength of this correlation vary across populations and assessment tools. Understanding this relationship in residential care environments provides data for healthcare workers, especially physiotherapists, occupational therapists, and geriatric specialists to develop individualized exercise programs, optimize mobility, and implement effective fall-prevention measures. Hence, the aim of this research is to evaluate the correlation between functional ability and fall risk among institutionalized elderly persons. Through recognizing the degree to which physical function predicts fall probability, this research aims to advance evidence-based geriatric care and support the development of interventions to minimize falls and preserve functional independence.

METHODOLOGY

Study design

This research used a quantitative, cross-sectional design with aim to examine the relationship between functional ability and fall risk among institutionalized elderly persons. This research focused on evaluating how levels of independence in activities of daily living as measured by the Barthel Index, correlate with general functional capacity and susceptibility to falls. This design enabled the collection of objective data at a single time point to assess patterns of dependence and functionality within the population.

Setting and participants

The research was conducted in a residential care home for elderly individuals located in Kravari, Bitola, North Macedonia. A total of 30 participants were included in the analysis,

selected through convenience sampling from residents who met inclusion criteria. Inclusion criteria required participants to be aged 50 years or older, have been institutionalized for at least three months, be cognitively capable of participating in the evaluation or have assistance from caregivers when necessary. Exclusion criteria included acute illness, terminal medical conditions, or refusal to participate. The sample consisted of 18 females (60%) and 12 males (40%), with ages ranging from 53 to 89 years (mean = 70.9 ± 9.2 years). The largest age group was between 70-79 years (36.7%), followed by 60-69 years (30%) and 80–89 years (20%).

Instrument

Functional ability was evaluated using the Barthel Index, a standardized and validated scale that measures performance in ten activities of daily living: feeding, bathing, personal hygiene, dressing, defecation, urination, toileting, transfer, mobility, and stair climbing. Each item was scored on a scale reflecting the level of independence: 0 points = complete dependence, intermediate scores = partial assistance required, maximum score per item = full independence. The total possible score ranges from 0 to 100, where higher scores indicate greater independence. Based on established cut-off points, participants were classified as independent (100 points), moderately dependent (61-90), severely dependent (21-60), or totally dependent (0–20). The Barthel Index was chosen for its simplicity, clinical applicability, and strong reliability in assessing self-care and mobility among older adults.

Data collection

Data were collected through direct observation, structured interviews, and review of clinical records. Each performance of the participant in the Barthel Index items was evaluated by trained physiotherapists and nurses working at the institution. In cases of communication difficulty, caregiver input was included to ensure accuracy. All data were recorded in standardized forms and transferred to Microsoft Excel for organization and statistical analysis.

Statistical analysis

Descriptive and inferential statistical analyses were performed to examine functional ability patterns and their relationship with fall risk. Frequencies, percentages, means, standard deviations, minimum, and maximum values were calculated for demographic variables and Barthel Index scores. Pearson correlation coefficients were computed to assess relationships between individual Barthel Index subdomains and total functional independence scores. Independent samples t-tests were used to test gender differences in total Barthel scores. One-way analysis of variance was applied to compare independence levels across age groups. Multiple linear regression analysis was performed to identify which activity of daily life variables predicted the total Barthel Index score.

RESULTS

Table 1: Gender of participants.

Gender	Number of participants	%
Female	18	60
Male	12	40

Table 1 shows the gender of the participants included in this research. Out of 30 participants, 18 (60%) were female and 12 (40%) were male. These results give us a predominance of female participants in the sample, and this result aligns with general demographic trends observed in research involving older populations, where women show higher representation due to greater life expectancy.

Table 2: Age of the included participants.

Age	n	%
50-59	4	13.33
60-69	9	30
70-79	11	36.67
80-89	6	20
Mean ± Standard deviation	30	70.9 ± 9.2 Range: 53-89

Table 2 shows the age of the participants involved in this research. The largest proportion of participants (36.7%) were between 70 and 79 years old, followed by those of 60-69 years (30%) and 80-89 years (20%). A smaller number of participants (13.3%) were between 50 and 59 years old, and none were aged 90 or above. The genera; mean age was 70.9 ± 9.2 years, ranging from 53 to 89 years, showing that most participants belonged to the older adult population typically encountered in rehabilitation and functional independence assessments.

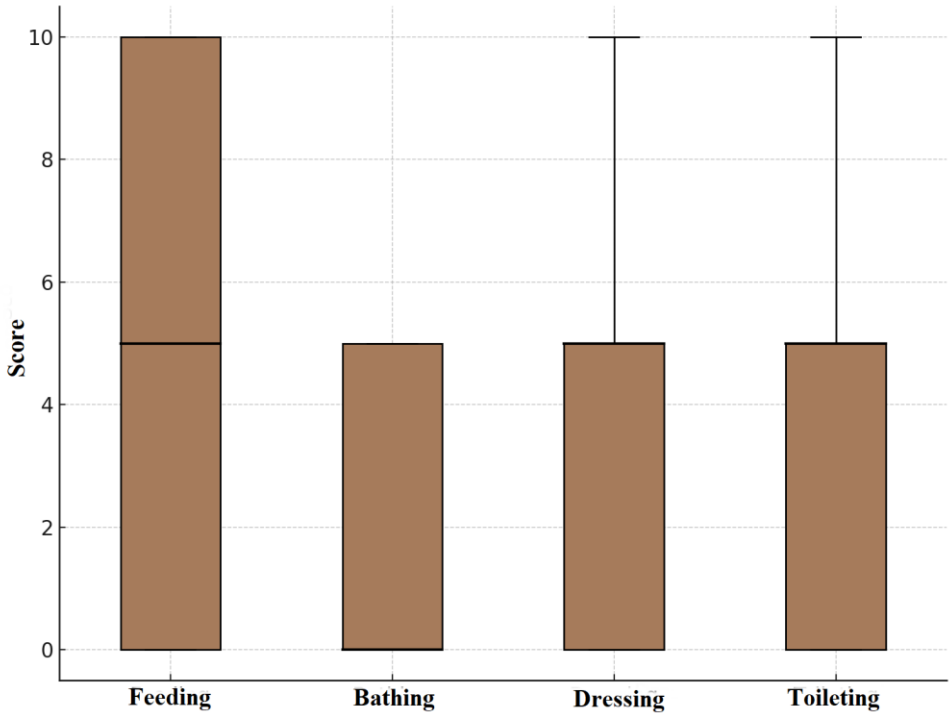

Figure 1: Distribution of basic activities of daily living - feeding, bathing, dressing, and toileting.

Figure 1 shows the variability in the performance of participants across four basic activities of daily living: feeding, bathing, dressing, and toileting. The median and interquartile ranges show differences in independence levels, with feeding showing the highest general performance, showing greater self-sufficiency. In contrast, bathing shows the lowest median score, indicating higher dependence in this category. The wider spread of scores in dressing and toileting suggests moderate variability among the persons, likely indirectly showing differing rehabilitation progress and physical limitations. The results from this figure show that personal hygiene and mobility activities tend to decline earlier than feeding ability.

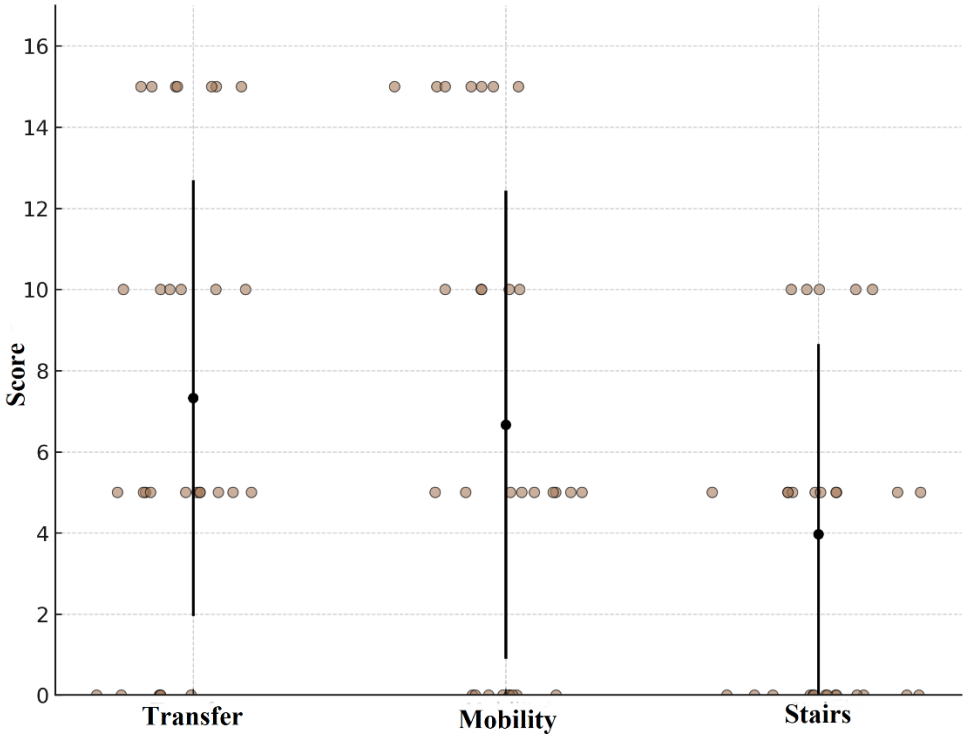

Figure 2: Distribution of functional mobility scores - transfer, mobility and stairs with individual data points.

Figure 2 shows the individual distribution of scores for the functional mobility categories - transfer, mobility and stairs as assessed by the Barthel Index. Each brown circular marker shows a score of each participant, visualizing variability in performance across the sample. The overlaid black dots and error bars indicate the mean ± standard deviation for each category, providing a clear view of central tendency and data dispersion. The results show that participants showed moderate independence in transfer and mobility activities, whereas stair climbing showed the lowest mean score and the highest variability, defining greater physical challenge and balance limitations in this category. The pattern shows the progressive decline in functional mobility associated with increasing physical demands of each activity.

Table 3: General functional independence levels based on total Barthel Index scores.

Functional independence level	n	%
Independent	3	10
Moderate dependence	7	23.33
Severe dependence	12	40
Total dependence	8	26.67
Mean ± standard deviation, range)	30	47.83 ± 32.92 (0-100)

Table 3 shows the general functional independence levels of the participants according to their total Barthel Index scores. The results reveal that the largest proportion of participants (40%) showed severe dependence, followed by 26.7% classified as totally dependent, indicating a high level of assistance required for daily functioning. A smaller sample of the participants showed moderate dependence (23.3%), while only 10% achieved full independence across all assessed categories. The general mean Barthel Index score was 47.83 ± 32.92, with scores ranging from 0 to 100, indicating substantial variability in the levels of independence of the respondents. These findings show the predominance of functional

limitations within the sample, defining the need for continuous and individualized rehabilitation to improve self-care and mobility.

Table 4: Pearson correlations between Barthel Index subcategories and total functional independence score.

Subcategory	*r*	*p*-value
Mobility	0.927	< 0.001
Transfer	0.897	< 0.001
Toileting	0.861	< 0.001
Defecation	0.845	< 0.001
Dressing	0.819	< 0.001

Table 10 show the results of the Pearson correlation analysis examining relationship between individual Barthel Index subcategories and the total functional independence score. All subcategories showed strong positive correlations with the total score ($r = 0.819–0.927$, $p < 0.001$), indicating that higher performance in each specific activity of daily living corresponds to greater general independence. The strongest relationships were observed for Mobility ($r = 0.93$) and Transfer ($r = 0.90$), showing their roles in determining general functional autonomy. These results show that rehabilitation for mobility and transfer training may produce the greatest impact on improving total independence levels in institutionalized or post-rehabilitation persons.

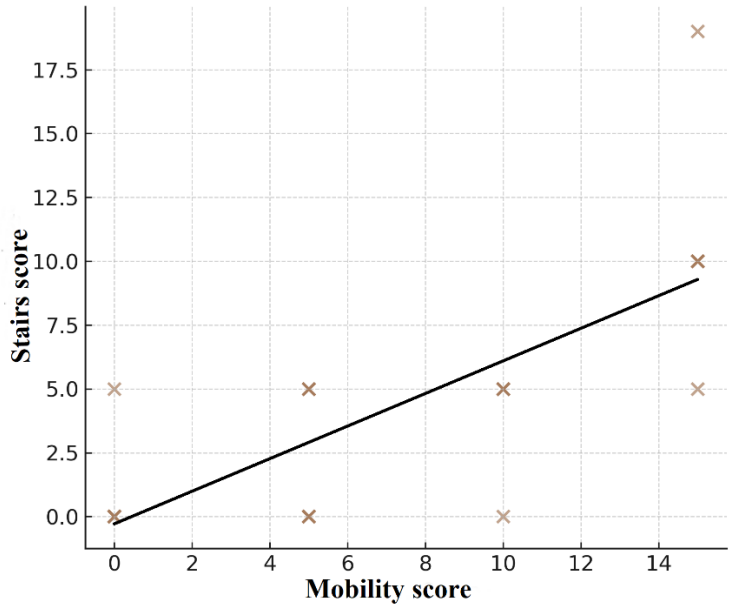

Figure 3: Relationship between mobility and climbing stairs.

Figure 3 shows the positive linear relationship between mobility and stair-climbing as assessed by the Barthel Index. Each point represents an individual score of the participants, with the regression line showing the general trend. A strong and statistically significant correlation ($r = 0.785$, $p < 0.001$) shows that participants with greater mobility capacity also achieved higher stair performance. This suggests that lower limb strength, coordination, and balance contribute to both categories.

Table 5: Multiple linear regression predicting total functional independence.

Predictor	B (unstandardized coefficient)	Std. error	*t*	*p*-value
Constant	2.883	2.067	1.395	0.176
Feeding	1.573	0.390	4.030	0.001
Bathing	0.843	0.634	1.330	0.197
Dressing	1.176	0.532	2.209	0.037
Toileting	2.123	0.484	4.385	< 0.001

Table 11 show the results of a multiple linear regression model examining the predictive contribution of key activities of daily living on total functional independence as measured by the Barthel Index. The model was statistically significant ($F(4,25) = 25.18$, $p < 0.001$) and accounted for 89.1% of the variance in total independence, indicating excellent explanatory power. Among the predictors, toileting ($B = 2.12$, $p < 0.001$), feeding ($B = 1.57$, $p = 0.001$), and dressing ($B = 1.18$, $p = 0.037$) showed as significant determinants of total functional capacity. In contrast, bathing showed no significant predictive value ($p = 0.197$), possibly due to uniformity of scores or reliance on environmental adaptations. These results show that self-care and toileting abilities are important categories influencing functional recovery and should be prioritized in rehabilitation to improve independence.

DISCUSSION

The results of this research show the relationship between functional ability and fall risk among elderly residents that are institutionalized, showing patterns of dependency and interdependence between various activities of daily living. The general results show that the majority of participants showed severe or total dependence, pointing out the vulnerability of this population to both physical and environmental problems that compromise autonomy. Strong correlations were observed between mobility, transfer, and toileting categories and the total Barthel Index score, suggesting that these areas play a big role in maintaining general functional independence. The significant predictive value of toileting, feeding, and dressing further shows the importance of preserving basic self-care and postural control abilities as important components of fall prevention. These results confirm that functional deterioration and fall susceptibility are connected phenomena, and they support the need for comprehensive rehabilitation with focus on mobility improvement, balance training, and individualized support to sustain independence and reduce fall risk among institutionalized elderly persons.

The results of Zak et al. (2015) complement the results of our research, showing the close link between reduced functional capability and elevated fall risk among institutionalized older adults. Their research on post-arthroplasty patients showed that limited mobility, multiple comorbidities, and medication use increased fall susceptibility, results that align with our research - mobility, transfer, and toileting independence were decisive factors in maintaining general functionality.

Another research by Nascimento et al. (2024) also supports our results by showing the influence of functional capacity, balance, and physical activity levels on fall risk among older adults. Their research showed that institutionalized elderly individuals showed poorer balance and mobility than physically active or exercising peers, yet experienced fewer actual falls, likely due to reduced environmental exposure and controlled living conditions. These results connect with our observation that participants with greater dependence in mobility and transfer categories showed lower general functional independence.

One study by Baixinho et al. (2022) in their research showed a high prevalence of falls (41.6%) and frequent recurrence, especially among residents with cognitive impairment

who showed lower adherence to safety and self-care practices. Similarly, our research revealed that deficits in functional independence, especially in mobility, toileting, and transfer activities contributed to increased fall risk within institutional environments. The research by Poncumhak et al. (2025) complements with our research by showing the predictive relationship between fear of falling, functional balance, and fall risk in older adults. Their analysis of community-dwelling elderly showed that persons with greater fear of falling, as measured by the newly developed FOF-10 Scale, showed poorer balance and higher fall incidence, with strong correlations between FOF-10, TUG, and FES-I scores (ρ = 0.929–0.573, $p < 0.001$). These results connect with our study where reduced functional independence was associated with elevated fall susceptibility among institutionalized residents.

Limitations and future directions

This research has several limitations that should be acknowledged. The relatively small sample size limits the generalizability of the results and may not fully represent the diversity of functional profiles among institutionalized elderly persons. Also, the cross-sectional design prevents establishing causal relationships between reduced functional ability and fall risk, as changes in independence levels and rehabilitation could not be observed. The research also relied solely on the Barthel Index for assessing functional independence; while this tool is widely validated, incorporating complementary assessments such as balance and gait tests could have provided a more comprehensive understanding of fall-related factors.

Future research should define these limitations through longitudinal researches that track changes in functional capacity and fall occurrence over time, as well as through larger, multicenter samples to strengthen external validity. Integrating physical, cognitive, and psychological assessments in future models could enable a more holistic approach to fall-risk evaluation.

CONCLUSIONS

The results of this research confirm a strong interrelationship between functional ability and fall risk among institutionalized elderly persons. The majority of participants showed severe or total dependence, defining their vulnerability to mobility decline and recurrent falls. The most important determinants of general independence were mobility, transfer, and toileting, which together accounted for the majority of variance in total functional capacity. These results define the need for individualized rehabilitation programs with focus on postural control, strength training, and the restoration of self-care abilities. Prioritizing these domains, healthcare workers could reduce fall risk, improve independence, and promote safer aging within institutional care environments.

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FOOD SYSTEMS TRANSFORMATION TOWARDS SUSTAINABILITY AND HEALTHIER GLOBAL NUTRITION

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ABSTRACT

Introduction: *The global food system encompasses interconnected activities including food production, processing, distribution, consumption, and waste management. However, this system significantly contributes to environmental degradation, with approximately 30% of global greenhouse gas emissions originating from food production and its associated processes. This review addresses the urgent need to transition toward sustainable food systems that can support both human and planetary health. The objective is to explore the role of the agri-food sector, alongside governmental and other stakeholders, in promoting sustainable healthy diets—defined as dietary patterns that are health-promoting, accessible, affordable, safe, equitable, and culturally appropriate.*
Methods: *The methodological approach consisted of a comprehensive literature review, analyzing current research, reports, and policy documents to assess the effectiveness of interventions in improving nutrition and reducing environmental impact. The review also examines strategies such as food reformulation, development of functional foods, waste valorization, and public education aimed at changing consumer behavior.*
Results: *Findings highlight the critical role of sustainable food systems in addressing the double burden of malnutrition—where undernutrition and obesity coexist—and in preventing non-communicable diseases. The evidence indicates that improving food availability, affordability, and quality through coordinated actions among the agri-food sector and policymakers can significantly contribute to better health outcomes and reduced environmental impact.*
Discussion: *This review underscores the importance of systemic change in food production and consumption patterns. It concludes that equitable access to nutritious food, combined with education and innovation in food production, are essential to achieving the United Nations' Sustainable Development Goals.*

Keywords: Food system, Functional food, Food reformulation, Stakeholders, Malnutrition

1. Introduction

The transformation of global food systems has emerged as one of the most pressing challenges of the 21st century, intersecting issues of public health, environmental sustainability, and socio-economic development. According to Biesbroek et al. (2023), sustainable food systems aim to ensure equitable access to nutritious foods across all income levels while simultaneously supporting the livelihoods of smallholders and small to medium-sized enterprises, thereby fostering greater social inclusivity. This vision aligns closely with the United Nations' Sustainable Development Goals (SDGs), which highlight the central role of sustainable food systems in achieving healthy diets and broader societal well-being.
A growing body of research underlines the need for a comprehensive transformation of current food systems to address these interconnected challenges, advocating for ecologically sustainable dietary patterns that promote both nutritional health and food security. However, implementing such systemic changes remains complex and resource-intensive (Hales et al., 2024).

The food system represents a highly intricate and interdependent network encompassing agriculture, animal husbandry, food production and processing, distribution, marketing, retail, preparation, and consumption (Martinelli & Cavalli, 2019). Dietary and food choices exert substantial environmental impacts through multiple pathways, including energy consumption, land conversion, water resource depletion, and contributions to climate change (Macdiarmid, 2013). The entire food supply chain — from fertilizer production to global commodity distribution — contributes significantly to greenhouse gas emissions (Campbell et al., 2017). Food production alone accounts for approximately 30% of global greenhouse gas emissions (Bailey & Harper, 2015), illustrating its disproportionate environmental footprint. Current dietary patterns are widely regarded as unsustainable, as they rely heavily on resource-intensive foods that require large energy inputs and extensive land use, resulting in substantial ecological degradation (Martinelli & Cavalli, 2019).

Sustainable healthy diets, as defined by the World Health Organization (2019), are dietary patterns that promote comprehensive health and well-being, are accessible, affordable, safe, fair, and culturally acceptable. In response to the growing environmental and public health challenges associated with current dietary patterns, an increasing number of countries have integrated sustainability principles into their national dietary guidelines. These recommendations emphasize a shift towards predominantly plant-based diets, prioritizing seasonal and locally sourced foods, reducing food waste, and limiting the consumption of red and processed meats, ultra-processed products, and sugar-sweetened beverages (Goulding et al., 2020).Non-communicable diseases (NCDs) represent one of the most significant public health burdens worldwide, accounting for approximately 74% of all deaths in 2019 (WHO, 2021). The 2021 Global Nutrition Report underscores the urgency of addressing diet-related health risks, as more than 2.2 billion adults are now overweight or obese, with prevalence rates rising rapidly in low- and middle-income countries, particularly in urban settings(https://www.who.int/health-topics/obesity#tab=tab_1). Evidence from the Food Consumption Survey in Adults in Macedonia (2015) reflects this trend, with 62.7% of men and 48.4% of women classified as overweight or obese—figures comparable to those in many European countries (Spiroski, 2016).

Unhealthy dietary patterns remain a major modifiable risk factor for overweight, obesity, and diet-related NCDs, contributing substantially to global morbidity and mortality (Barclay & Haschke, 2015; Afshin et al., 2014).The COVID-19 pandemic further exposed the vulnerability of food systems, highlighting the critical role of adequate nutrition in population health. Malnutrition was associated with increased risk and severity of SARS-CoV-2

infection, reinforcing the importance of resilient and equitable food environments (Huizar et al., 2021; Wells et al., 2021; Pan et al., 2021).

Food choices are strongly shaped by the availability and accessibility of products within commercial food systems, upon which most populations depend for daily nourishment(White et al., 2020). In this context, agri-food by-products have attracted growing attention as a promising resource for sustainable food innovation. Due to their richness in proteins, lipids, carbohydrates, micronutrients, dietary fiber, and diverse bioactive compounds, these by-products offer significant potential for the development of novel food formulations, alternative livestock feeds, and the recovery of functional ingredients (Rațu et al., 2023).Transitioning to sustainable food systems is therefore essential to protect both human and planetary health. Achieving this transformation requires integrated, multisectoral strategies that balance ecological integrity with nutritional security and equitable access to resources, while building resilience to future global health and environmental crises.

This paper examines the current state of global food systems, identifies their environmental and nutritional impacts, and outlines key strategies for their transformation towards more sustainable and health-promoting models.

The agri-food sector as a central component of food systems transformation

The agri-food sector functions as an interconnected system comprising agriculture, food processing, and trade, which constitute the core components of this integrated network (Karwacka et al., 2020).The unsustainability of current food systems is driven by a complex interplay between environmental degradation, inefficient resource use, and nutrition-related health challenges. Modern agricultural systems are characterized by intensive production models, monocultures, and heavy reliance on synthetic fertilizers and pesticides, which contribute to soil degradation, biodiversity loss, water pollution, and increased greenhouse gas emissions (FAO, 2023). Furthermore, current food supply chains are heavily dependent on fossil fuels, long-distance transportation, and energy-intensive processing, which substantially increase the sector's carbon footprint. Approximately one-third of all food produced globally is lost or wasted each year (FAO, 2021), highlighting the systemic inefficiencies embedded across production, distribution, and consumption stages.

Commercial food systems have undoubtedly contributed to the current global state of food environments (Cetthakrikul et al., 2019). Profits can be made from a healthier and more sustainable food system, in ways that are consistent with prevention of diet-related diseases including diabetes, heart disease, stroke, and cancer. The food industry is an inevitable actor in the action to develop, distribute, and market healthier foods for society. The food industry is responding to this challenge by improving the nutritional value of food products through decreasing the levels of public health-sensitive nutrients and increasing the content of essential nutrients (fiber, micronutrients, etc.) (Barclay & Haschke, 2015). Saturated fats, industrially produced trans fats, sodium, and added sugars, which are known as dietary factors that can contribute to the risk of certain non-communicable diseases (NCDs) when consumed in excess, are now recognized and implemented in programs with criteria built on the concepts of "nutrients to limit" in multinational companies (Yach et al., 2010; PepsiCo Nutrition Criteria).

Given the significant health and economic burden of diet-related diseases, overweight status, and obesity and the need for multi-stakeholder solutions because of the multifactorial nature of the public health concerns, a coordinated national food and nutrition policy strategy should be a priority for all governments (Mozaffarian et al., 2018)a. Governments can use a spectrum of policies, from voluntary to mandatory, focused on altering consumer preferences or choice, food formulations, or food availability and accessibility.

Governments need to increase their efforts to catalyze and regulate rapid change in the food sector, through fiscal and regulatory policies that will support the implementation of nutritional strategies. In the implementation of healthy food policies, food companies should have the role of facilitators in that process and by using their expertise, innovation, and marketing to develop, distribute, and market healthier foods and create transparent, genuine partnerships with academics, advocacy groups, and the government (Mozaffarian et al., 2018a; Chen & Yang, 2021; Wang et al., 2016). In Figure 1, the food industry's role and interactions between the food industry and other stakeholders for a healthier food system are shown.

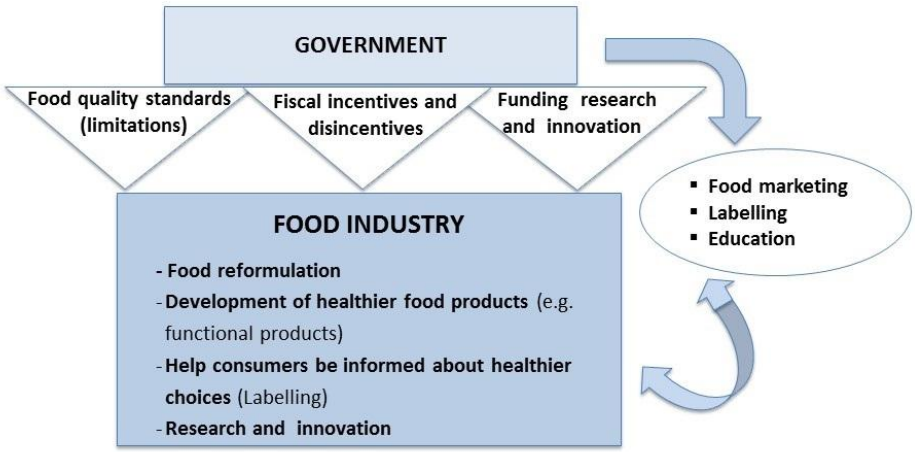

Figure 1: Food industry role and interactions between food industry and other stakeholders for a healthier food system

A law that imposes sales tax on sugar-sweetened beverages (SSB), discourages consumers from buying these beverages, and encourages manufacturers to develop low-sugar alternatives is just one example (Kobes et al., 2022). Numerous public–private partnerships nowadays (for example, the International Diabetes Federation and Nestlé) (Moodie et al., 2013) also contribute. However, some food companies have actively opposed healthier food policies, especially in low- and middle-income countries (Mozaffarian et al., 2018)a. Taking responsibility to improve the nutritional quality of food products could increase companies' chances of market success because of increased government and consumer trust and loyalty toward these companies (Harastani et al., 2020).

3. Addressing the rise of ultra-processed foods: reformulation and innovation pathways

The agri-food sector, as a central component of the global food system, holds significant responsibility for shaping the nutritional quality and sustainability of available food products. While ongoing efforts from governments and the food industry to promote healthier food environments and policies are crucial, addressing the complexity of dietary patterns requires a deeper understanding of the types of foods consumed, particularly the rising dominance of ultra-processed foods (UPFs).

Ultra-processed foods (UPFs) are defined as "formulations of ingredients, mostly of exclusive industrial use, typically created by a series of industrial techniques and processes" (FAO, 2019). There is strong nutritional epidemiological evidence of an association between UPF consumption and an increased risk of morbidity and mortality (Campbell et al., 2021). UPF products now dominate the food supplies of various high-income countries (Monteiro et

al., 2017) and it is argued that the world's population will consume more ultra-processed foods and drinks over the coming decades than ever before (Moodie et al., 2013). For example, UPFs accounted for 56.1% of the total energy ingested by the participants in the study of Juul et al., 2018, conducted among US adults. UPFs are highly profitable and mainly produced by multinational corporations (Lauber et al., 2020). UPF products are nutritionally inferior to unprocessed, minimally processed, or processed foods as they contain significantly higher proportions of carbohydrates, free sugars, total and saturated fats, salt, and energy density and lower proportions of protein, fiber, vitamins, and minerals (Campbell et al., 2021).

To help tackle obesity, nutrients linked with negative health effects such as sugar, fat, and salt can be reduced from ultra-processed foods in a process called "Food Reformulation" (Harastani et al., 2020). In the last decade, reformulation of the food supply is viewed as the best investment for preventing diet-related diseases and has been implemented in many countries (Grunseit et al., 2021). More recently, the focus of reformulation policies has shifted to added sugar and energy reduction, and sparse initiatives have been launched to increase the nutrient density of foods by increasing their amount of fiber, whole grains, or specific fats such as omega-3 (Gressier et al., 2020).

Food reformulation can have significant impacts on public health, but realizing this potential will require more clarity and consensus on the underlying notions and mechanisms by which reformulation can affect people's diets and health (Gressier et al., 2020). However, the daily intake of all unhealthy foods and nutrients still exceeds the recommended amount globally, coinciding with inadequate healthy food consumption (e.g., sugar-sweetened beverage consumption - SSB) (GBD 2017 Diet Collaborators, 2019). At the same time, nearly all healthful foods and nutrients are consumed in insufficient amounts globally.

Functional foods are a category of foods that are promoted as having health benefits (Urala & Lähteenmäki, 2007).Nowadays, the globally growing interest and acceptance of functional foods have a major impact on the market, and unlike decades ago, consumers are motivated and willing to consume functional foods (Kaur & Das, 2011). Foods that contain bioactive components are another interesting area for the food sector in obesity control (Binks, 2016). The potential synergy in formulations of foods containing anti-obesity bioactive food components attracts the attention of scientists (Kaur & Das, 2011). Obesity and many other chronic diseases are currently being discussed in relation to plant-derived antioxidants and their potential for prevention or even reversal (Deledda et al., 2021). Many antioxidant compounds have been examined and found to have anti-obesity, antioxidant, anti-dyslipidemia, and anti-diabetic potential (Khutami et al., 2022). Therefore, natural plant antioxidants could play important roles in controlling obesity, but well-designed clinical trials are necessary to better understand their effects (Pérez-Torres et al., 2021).

4. Implemented strategies and programs to promote healthier and more sustainable diets

A growing number of countries have developed strategies or action plans aimed at improving diet quality and reducing obesity prevalence (Roberto et al., 2015). Based on previous experiences and accumulated knowledge, it is evident that broader system-level, policy, and environmental strategies are required to achieve meaningful changes in dietary habits at both the individual and population levels (Mozaffarian et al., 2018)b.

4.1 Fiscal policy measures and taxation strategies

Fiscal policies represent one of the most widely implemented tools for the prevention of non-communicable diseases (NCDs). These include taxes (fiscal disincentives) on sugar-sweetened beverages (SSBs), unhealthy nutrients (saturated and trans fats, salt, sugar), and/or unhealthy foods (defined through nutrient profiling), as well as subsidies to promote the consumption of fruits, vegetables, and other healthy foods (WHO, 2016). The year 2016 has been referred to as "the year of the sugar tax" and currently more than 35 countries, states, and citieshave introduced some form of taxation on sugary beverages (Shahid & Bishop, 2019).

Evidence shows that increasing SSB taxes can lead to significant reductions in their purchase and consumption, resulting in health benefits and lower obesity prevalence — as demonstrated in Thailand (Phonsuk et al., 2021), Australia (Tangcharoensathien et al., 2019), Mexico and Chile (Fuster et al., 2020).Kaplan et al. (2024) reported that following the implementation of excise taxes on sugary beverages in five U.S. cities (Boulder, Philadelphia, Oakland, Seattle, and San Francisco), purchases declined significantly and continued to decrease over time.

4.2 Advertising regulation and front-of-package labeling

Advertising has a substantial impact on consumer behavior. Products most heavily advertised are often nutritionally poor and inconsistent with healthy dietary recommendations (Obesity Action Scotland, 2019). For example, according to Obesity Action Scotland, only 2.5% of annual food and drink advertising expenditures in 2017 were directed at fruits and vegetables, while 46% promoted confectionery, sweet and savory snacks, and soft drinks.

The widely used policy tool is ***front-of-package labeling***, which provides consumers with accessible information on products that can harm health, thereby guiding purchasing decisions (Dintrans et al., 2020; Osiac et al., 2018). This approach is simple, cost-effective, and increasingly adopted worldwide.Some countries are implementing more comprehensive strategies that combine multiple policy elements — such as taxation, advertising restrictions, labeling, and sales regulation in specific environments (e.g., schools). These integrated approaches are particularly effective in modifying food environments and consumer behavior, creating synergies between policy instruments.

4.3 Food waste reduction and circular economy solutions

A key component of sustainable food system transformation involves minimizing food waste along the entire supply chain (Campbell et al., 2017). Recycling and bioconversion of food waste offer promising strategies for sustainable development, enabling the conversion of waste materials through microbial fermentation into value-added products such as enzymes, food and feed additives, fertilizers, biofuels, animal feed, food-grade pigments, single-cell protein (SCP), and other valuable chemicals (Tropea et al., 2022).

Household food waste has also been used as a source for biogas production, which serves as renewable energy in transportation, such as biogas-powered buses (Liu et al., 2022). Effective waste reduction requires raising awareness among retailers and consumers about purchasing behaviors, challenging cultural norms and expectations, and, in some cases, revising relevant legislation (Guterres, 2019). Integrating environmental and nutritional information on food labels — with the latter already widespread — provides consumers with critical data to make informed choices (Bailey & Harper, 2015).The implemented strategies and programs clearly demonstrate that a combination of fiscal policies, regulatory measures,

and environmental interventions can effectively shape healthier and more sustainable food environments. However, the success of these interventions depends not only on their design and enforcement but also on continuous monitoring, evaluation, and adaptation to local contexts.

4. Future perspectives for sustainable and healthy food systems

Evidence consistently shows that healthy foods are relatively more expensive than unhealthy options, which creates a barrier for many consumers and widens nutritional inequalities (Abay et al., 2022; Kahan & Zvenyach, 2016; Hawkes et al., 2015). This gap represents an opportunity for governments and other stakeholders to intervene strategically. In particular, governments can implement fiscal measures that reduce the price gap between healthy and unhealthy foods by offering incentives to food producers and retailers to make healthier options more affordable. Additionally, policy-makers, local authorities, and political stakeholders have a crucial role in creating enabling environments that promote and encourage healthier choices at the population level (Kobes et al., 2022).

Tariff regulations may serve as powerful tools to discourage the consumption of unhealthy foods and to promote healthier alternatives (Abay et al., 2022). The food industry, in turn, should be further oriented toward food reformulation and the development of functional foods, ensuring healthier choices without compromising food safety. While reformulation can substantially improve the nutritional profile of foods, maintaining sensory attributes such as taste remains a major challenge (Shahid & Bishop, 2019).

The implementation of clear, easily recognizable food labeling systems for reformulated products could help consumers make informed decisions without the need for extensive label reading. A well-designed labeling strategy should be an integral part of broader nutrition policies, providing consumers with simple and practical information on products that may pose health risks and guiding healthier purchasing behaviors (Rosewarne et al., 2020).

Ultimately, integrated policies, strategic investments, and culturally sensitive approaches are essential to drive meaningful change across multiple sectors, including food production and manufacturing, workplaces, schools, healthcare systems, nutrition support programs, and research and innovation (Mozaffarian et al., 2018)b. Public–private partnerships and multisectoral collaboration are critical for achieving these goals.

Moreover, the agri-food sector remains one of the most important actors in this process. Strengthening its role in developing sustainable food systems can indirectly contribute to reducing obesity prevalence and diet-related NCDs while ensuring long-term environmental and economic sustainability.

5. Conclusions

The agri-food sector represents a pivotal actor in the transformation towards healthier and more sustainable food systems. Its involvement is crucial in developing, distributing, and marketing healthier food options that align with public health goals and environmental sustainability. Reformulation programs, aimed at improving the nutritional profile of foods while maintaining product quality and consumer acceptance, should be embedded within a comprehensive food and nutrition strategy. Such a strategy must be supported by strong governmental policies and public awareness campaigns that encourage healthier dietary behaviours and shift consumption patterns towards more sustainable and balanced diets (Rosewarne et al., 2020).

Given the increasing consumer interest and willingness to adopt functional foods (Kaur & Das, 2011) the integration of bioactive components into food products offers an additional, promising pathway for addressing obesity and related non-communicable diseases (Binks, 2016).

However, real and lasting change will require coordinated, multisectoral action involving governments, the private sector, academia, and civil society. Aligning health, agricultural, economic, and environmental goals will be key to ensuring that food system transformation leads to measurable health benefits, reduced disease burden, and improved population well-being.

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